

SOUTHWEST FISHERIES CENTER ADMINISTRATIVE

REPORTS, 1975

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CONTRIBUTIONS TO NMFS ANNUAL REPORT

Increased fishing effort expended on the South Pacific albacore, Thunnus alalunga, in the past 10 years has resulted in a decline of over 60% in apparent abundance. Preliminary CPUE estimates for early 1974 are alarmingly low. A further increase in harvesting pressure is proposed. SWFC HL, therefore, has undertaken an assessment of this fishery. Results show that the maximum sustainable "average" yield is estimated to be 33,000-35,000 MT. Based on the generalized production model of Pella and Tomlinson, a 25% increase in fishing effort over the 1971 level could result in a moderate catch increase of 300 MT or a decline of 6,700 MT, depending on the measure of fishing effort used.

The HL, in a search for ways to augment the often-inadequate supply of baitfish used in pole-and-line skipjack tuna fishing in the central and western Pacific Ocean, experimented with transporting the northern anchovy, Engraulis mordax, from California to Hawaii. Holding tanks for acclimatizing the anchovy prior to shipping were set up at the site of the bait supply. Bait density and survival experiments were completed. With various degrees of success several loads of anchovy were carried to Hawaii in a 5,000-gallon baitfish transport tank, constructed from a surplus aircraft fuel transport trailer. At least two more trial shipments, carrying the recently determined optimum capacity of 0.34 pound per gallon, should result in a cost-effective survival rate of 70%.

In a major breakthrough, HL scientists have demonstrated the existence of three fundamental limits defining the extremes of the skipjack tuna habitat. First, these highly active animals require an abundance of oxygen; they cannot live for more than a few minutes in water of less than 3.5 ml/liter oxygen. Second, a lower temperature limit near 16°-18°C places a maximum limit on their depth distribution in higher latitudes wherever dissolved oxygen is not a factor. Third, an upper temperature limit is established by internal muscle temperatures generated by the animals' metabolism. The protein in the fish's muscle suffers irreversible damage at temperatures higher than about 35°C, so that the smallest (1 kg) fish must remain in water cooler than 30°; the largest (13 kg) in water cooler than 20°C.

[transmitted via telecopier to L. Vlymen, 1/10/75, 1200.]

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STATUS REPORT

Mercury in the Pacific Blue Marlin, Makaira nigricans

By

Cynthia S. Unninayar and Bernard M. Ito

INTRODUCTION

In 1971, nine species of pelagic and inshore fish from Hawaiian waters were analyzed for total and organic mercury (Rivers, Pearson, and Shultz, 1972). In eight of these species the organic mercury was greater than 80% of the total; a finding consistent with other mercury values reported in the literature (Westöo, 1967; Kamps, Carr, and Miller, 1972). In the Pacific blue marlin, however, this predominance of organic mercury was not found, but rather most of the mercury seemed to be either inorganic or an organic form which was not extractable by the organic mercury method. Because of the uniqueness of the marlin, additional samples were collected in 1972, 1973, and 1974 during the Hawaiian International Billfish Tournament in Kailua-Kona, Hawaii, to continue study of the mercury levels in this fish. This report deals primarily with our findings of 46 marlin obtained in July 1974.

METHODS

Total, organic, and inorganic mercury were determined using the flameless atomic absorption apparatus with a Perkin-Elmer 303 Atomic Absorption Spectrophotometer. Total Mercury: The homogenized sample was digested with concentrated nitric acid over low heat and further oxidized with potassium permanganate solution; excess oxidizing agents were reduced with hydroxylamine solution; mercury ions were then reduced to elemental mercury with stannous chloride and vaporized into the flameless atomic absorption apparatus. (Rivers et al., 1972). Organic Mercury: The homogenized sample was extracted with benzene in a separatory funnel containing HCl, NaCl, and water; the benzene layer was then transferred to another separatory funnel and extracted with 1% cysteine solution; a portion of the cysteine solution was transferred to a flask and oxidized with permanganate and persulfate; following reduction with hydroxylamine and stannous ion, the mercury was vaporized into the

flameless apparatus (Rivers et al., 1972). Inorganic Mercury: One gram of a 1:1 tissue:water homogenate was digested with 3 ml of concentrated nitric acid in a flask for 1 hour at room temperature then diluted to an appropriate volume with water, following reduction with stannous ion, the mercury was vaporized into the flameless apparatus (Iverson and Hierliky, 1974). Inorganic analyses were performed on samples of muscle and liver to confirm that the difference between total and organic was indeed inorganic mercury. The data are not reported here but does confirm that the residual mercury is inorganic in nature.

RESULTS AND DISCUSSION

Table 1 gives the results of total and organic mercury in muscle, liver, kidney, spleen, pyloric caecum, stomach, gill, gonad, and whole blood for 14 female (weighing 39-342 kg) and 32 males (weighing 58-112 kg) Pacific blue marlin. Total mercury levels were lowest in blood (0.01-0.61, $\bar{x}$ = 0.18 ppm) and highest in kidney (0.18-77.00, $\bar{x}$ = 26.33 ppm). In muscle the total values ranged from 0.09 to 10.00, $\bar{x}$ = 3.12 ppm. Organic mercury levels were lowest in blood (0.00-0.11, $\bar{x}$ = 0.04 ppm) and highest in muscle (0.02-1.02, $\bar{x}$ = 0.40 ppm). In all tissues the organic fraction was less than 1.02 ppm.

A general analysis of variance for the 1974 samples revealed significant differences between concentrations of total mercury in males and females and between body weight and tissues although these differences were not significant for organic mercury. Additional statistical analyses considered the two sexes separately for total mercury. Table 2 gives correlation coefficients between body weight and tissues. In most cases, the relationship is highly significant. The contrast of males and females shown in Figures 1 and 2 may be due to age and/or metabolic dissimilarities since females mature at a different rate than males. To see if this difference was the same for the previous years, an analysis of covariance was performed on all samples for muscle and liver beginning with 1971. The results indicated that there is no statistical dissimilarity between either males and females or between years. As was expected, however, there was a definite difference between muscle and liver tissues. In previous years, the number of females has been smaller than in 1974 perhaps resulting in a lack of a representative sample for comparison (Rivers et al., 1972; Shultz et al., in press).

The data clearly demonstrate that the organic mercury levels are quite low relative to the total mercury. Westöo (pers. comm.) has identified the organic fraction as methyl mercury in freeze-dried samples of the marlin. Both the Swedish Laboratory and the Tokyo Metropolitan Research Laboratory of Public Health (Nishigaki, pers. comm.) have confirmed the low percentages of organic mercury in samples collected in 1971 and 1974, respectively.

The ratio of total organic mercury for gonad, blood, gill, pyloric caecum, muscle, and stomach tissues range from about 4:1 to 11:1. The ratios in spleen, liver, and kidneys, however (38:1, 45:1, 120:1, respectively), reflect an unusually high proportion of inorganic to organic mercury in these organs. Many organisms have been reported capable of transforming methyl and other types of organic mercury to an inorganic form (Norseth and Clarkson, 1970a, 1970b; Takeda and Ukita, 1970; Burrows and Krenkel, 1973; Fang, 1973; Iverson and Hierliky, 1974). In most of these cases, the conversion was thought to occur or be associated with the kidney and liver.

Although the above demonstrations occurred under artificial laboratory conditions not necessarily applicable to the natural environment, they nevertheless offer convincing evidence that the conversion of methyl mercury to inorganic mercury in the Pacific blue marlin is an adaptive response to environmental mercury contamination.

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Table 1.--Total and organic mercury in tissues of 46 Pacific blue marlin, *Makaira nigricans* (milligram/kilogram wet weight; mercury calculated as inorganic mercury).

WT KG	SEX	TOTL HUSC	ORGN HUSC	TOTL LIVR	ORGN LIVR	TOTL KIDN	ORGN KIDN	TOTL SPLN	ORGN SPLN	TOTL STOM	ORGN STOM	TOIL P.C.	ORGN P.C.	TOTL GILL	ORGN GILL	TOTL COND	ORGN COND	TOTL BLD	ORGN BLD
39	F	0.09	0.02	0.13	0.13	0.18	0.04	0.08	0.02	0.06	0.06	0.17	0.08	0.21	0.02	--	--	0.02	0.02
58	M	0.33	0.16	0.22	0.11	0.78	0.09	0.19	0.05	0.09	0.06	0.20	0.11	0.19	0.02	0.03	0.03	0.03	0.03
60	M	0.52	0.40	0.78	0.39	0.77	0.20	0.26	0.16	0.18	0.08	0.36	0.17	0.19	0.05	--	--	0.11	0.03
60	M	0.98	0.32	3.60	0.25	7.10	0.12	1.78	0.13	0.48	0.08	0.61	0.23	0.31	0.05	0.10	0.06	--	--
63	M	1.68	0.18	4.65	0.19	8.45	0.16	1.80	0.10	0.60	0.06	0.80	0.26	0.13	0.03	0.27	0.09	0.11	0.05
64	M	0.72	0.15	3.35	0.19	8.35	0.16	2.12	0.12	0.43	0.08	0.61	0.21	0.12	0.03	0.12	0.05	0.06	0.03
64	M	1.96	0.14	7.00	0.09	17.80	0.09	2.60	0.03	0.86	0.06	1.12	0.13	0.24	0.01	0.22	0.03	0.03	0.03
66	M	1.32	0.24	5.44	0.13	10.20	0.10	0.94	0.02	0.50	0.06	1.02	0.12	0.14	0.02	0.13	0.03	0.06	0.02
68	M	0.36	0.12	2.25	0.10	4.60	0.07	0.88	0.10	0.36	0.04	0.42	0.13	0.08	0.01	--	--	0.03	0.01
68	M	2.20	0.42	3.00	0.24	16.10	0.19	4.00	0.06	0.83	0.11	0.96	0.31	0.18	0.03	0.16	0.13	--	--
69	M	0.66	0.32	1.30	0.23	3.10	0.14	0.64	0.05	0.17	0.11	0.42	0.18	0.08	0.03	0.08	0.07	3.05	0.04
72	M	2.00	0.32	11.45	0.13	19.60	0.15	4.05	0.05	1.05	0.08	1.07	0.14	0.22	0.02	0.18	0.05	0.04	0.02
72	M	1.64	0.16	8.90	0.16	15.40	0.10	4.85	0.16	1.06	0.03	--	--	0.25	0.01	--	--	0.06	0.02
73	M	2.72	0.24	13.40	0.11	29.40	0.07	--	--	1.12	0.04	1.39	0.15	0.20	0.01	0.10	0.07	0.04	0.03
75	F	3.44	0.56	5.70	0.28	16.20	0.26	5.75	0.11	0.90	0.09	1.02	0.32	0.31	0.05	--	--	0.03	0.02
75	M	3.60	0.32	19.80	0.19	30.80	0.16	6.95	0.13	2.10	0.15	3.04	0.17	0.25	0.03	0.40	0.05	0.03	0.02
75	M	1.88	0.26	13.60	0.16	16.00	0.15	4.70	0.06	1.72	0.04	1.24	0.15	0.28	0.02	0.40	0.05	--	--
75	M	1.80	0.18	15.60	0.11	18.00	0.06	3.90	0.10	--	--	1.30	0.08	0.25	0.02	0.26	0.04	--	--
76	M	3.04	0.31	15.00	0.14	21.00	0.12	--	--	1.30	0.04	1.70	0.14	0.26	0.02	0.26	0.03	0.39	0.04
79	M	3.60	0.36	13.40	0.39	18.20	0.19	6.95	0.22	1.84	0.15	2.10	0.40	0.39	0.08	0.40	0.13	0.58	0.09
79	M	2.16	0.36	9.60	0.36	21.40	0.14	4.70	0.14	1.14	0.11	1.60	0.33	0.21	0.05	0.25	0.05	0.63	0.05
79	M	3.60	0.38	11.80	0.15	24.00	0.15	5.40	0.12	1.18	0.06	2.50	0.21	0.27	0.02	0.27	0.05	--	--
82	M	3.32	0.20	14.00	0.10	46.40	0.09	12.80	0.03	2.10	0.05	1.60	0.20	0.35	0.01	0.64	0.03	0.07	0.01
85	M	3.60	0.33	24.80	0.20	42.50	0.13	11.50	0.08	2.72	0.09	2.65	0.23	0.33	0.03	0.30	0.05	0.00	0.02
86	M	4.12	0.41	15.40	0.33	36.50	0.13	10.60	0.19	--	--	2.40	0.29	0.24	0.05	0.31	0.12	0.06	0.05
93	M	5.50	0.35	20.40	0.11	40.00	0.20	11.40	0.11	2.28	0.06	2.80	0.17	0.53	0.08	0.26	0.10	0.12	0.05
96	M	3.90	0.32	9.60	0.22	27.00	0.19	7.00	0.12	1.54	0.02	1.65	0.27	0.32	0.02	0.37	0.07	0.61	0.04
97	M	3.90	0.56	23.20	0.33	41.00	0.28	10.00	0.23	1.54	0.12	3.00	0.29	0.32	0.04	--	--	0.05	0.04
101	M	4.80	0.39	30.60	0.24	77.00	0.19	13.80	0.16	2.04	0.14	3.05	0.28	0.29	0.05	0.52	0.05	0.16	0.05
102	M	5.80	0.50	39.20	0.27	77.00	0.22	11.40	0.12	3.00	0.09	2.40	0.27	0.34	0.03	0.70	0.08	0.57	0.05
104	M	3.90	0.39	--	--	39.50	0.39	11.40	0.12	2.10	0.11	3.95	0.27	0.34	0.03	0.64	0.05	0.14	0.04
112	M	5.65	0.35	15.60	0.15	56.00	0.15	12.80	0.12	1.74	0.05	3.95	0.16	0.44	0.03	--	--	0.24	0.04
112	M	6.50	0.58	21.00	0.28	37.00	0.26	11.20	0.19	2.00	0.15	2.10	0.28	0.32	0.03	0.41	0.08	0.12	0.05
115	F	0.80	0.46	4.80	0.30	6.00	0.19	1.40	0.12	0.44	0.11	0.60	0.23	0.15	0.03	0.15	0.10	0.05	0.04
118	F	1.28	0.66	5.60	0.21	9.00	0.28	4.10	0.18	0.56	0.10	0.60	0.19	0.20	0.07	0.35	0.29	0.05	0.04
135	F	1.68	0.41	3.40	0.22	9.00	0.26	3.60	0.22	0.88	0.17	1.25	0.30	0.35	0.07	0.33	0.20	0.10	0.05
140	F	1.82	0.65	5.20	0.35	7.50	0.37	6.20	0.39	0.84	0.30	1.55	0.58	0.35	0.15	0.24	0.11	0.13	0.11
149	F	0.84	0.36	2.80	0.34	4.00	0.25	2.90	0.29	0.80	0.21	1.10	0.41	0.38	0.09	0.23	0.19	0.09	0.06
155	F	7.20	0.86	20.40	0.42	57.00	0.37	17.60	0.46	2.24	0.39	3.85	0.65	0.59	0.14	0.84	0.43	0.40	0.09
181	F	4.00	0.67	5.60	0.68	26.00	0.58	9.70	0.58	1.46	0.28	3.45	0.84	0.35	0.15	0.39	0.17	0.53	0.09
188	F	4.00	0.65	15.40	0.42	48.50	0.26	7.30	0.30	0.84	0.21	2.30	0.32	0.50	0.09	--	--	0.45	0.02
190	F	3.90	0.42	8.60	0.23	24.50	0.24	9.50	0.25	0.96	0.15	1.75	0.31	0.46	0.08	0.48	0.10	0.11	0.05
222	F	5.30	0.92	16.00	0.46	51.00	0.35	17.40	0.21	1.54	0.21	3.25	0.74	0.66	0.08	--	--	0.19	0.32
260	F	8.40	0.92	16.00	0.58	36.50	0.56	13.20	0.45	1.96	0.24	3.05	0.82	0.69	0.22	1.60	0.25	--	--
342	F	10.00	1.02	16.80	0.76	76.00	0.86	16.20	0.66	2.72	0.47	4.50	0.98	0.96	0.34	2.15	0.65	--	--
Mean	106	3.12	0.40	11.58	0.26	26.33	0.22	6.93	0.18	1.27	0.12	1.83	0.30	0.32	0.06	0.40	0.11	0.18	0.04

Table 2.--Correlation coefficients for body weight and tissue for males and females for total and organic mercury.

Muscle	Liver	Kidney	Spleen	Stomach	Pyloric caecum	Gill	Gonad	Blood
<u>Body weight/male--Total mercury</u>								
0.898**	0.765**	0.830**	0.884**	0.773**	0.828**	0.696**	0.751**	0.318
<u>Body weight/female--Total mercury</u>								
0.834**	0.694**	0.795**	0.759**	0.822**	0.820**	0.897**	0.947**	0.575**
<u>Body weight/male and female--Organic mercury</u>								
0.794**	0.762**	0.865**	0.837**	0.812**	0.859**	0.877**	0.823**	0.358*

*P<0.05

**P<0.01

Figure 1 Total and organic Hg in muscle vs Body weight

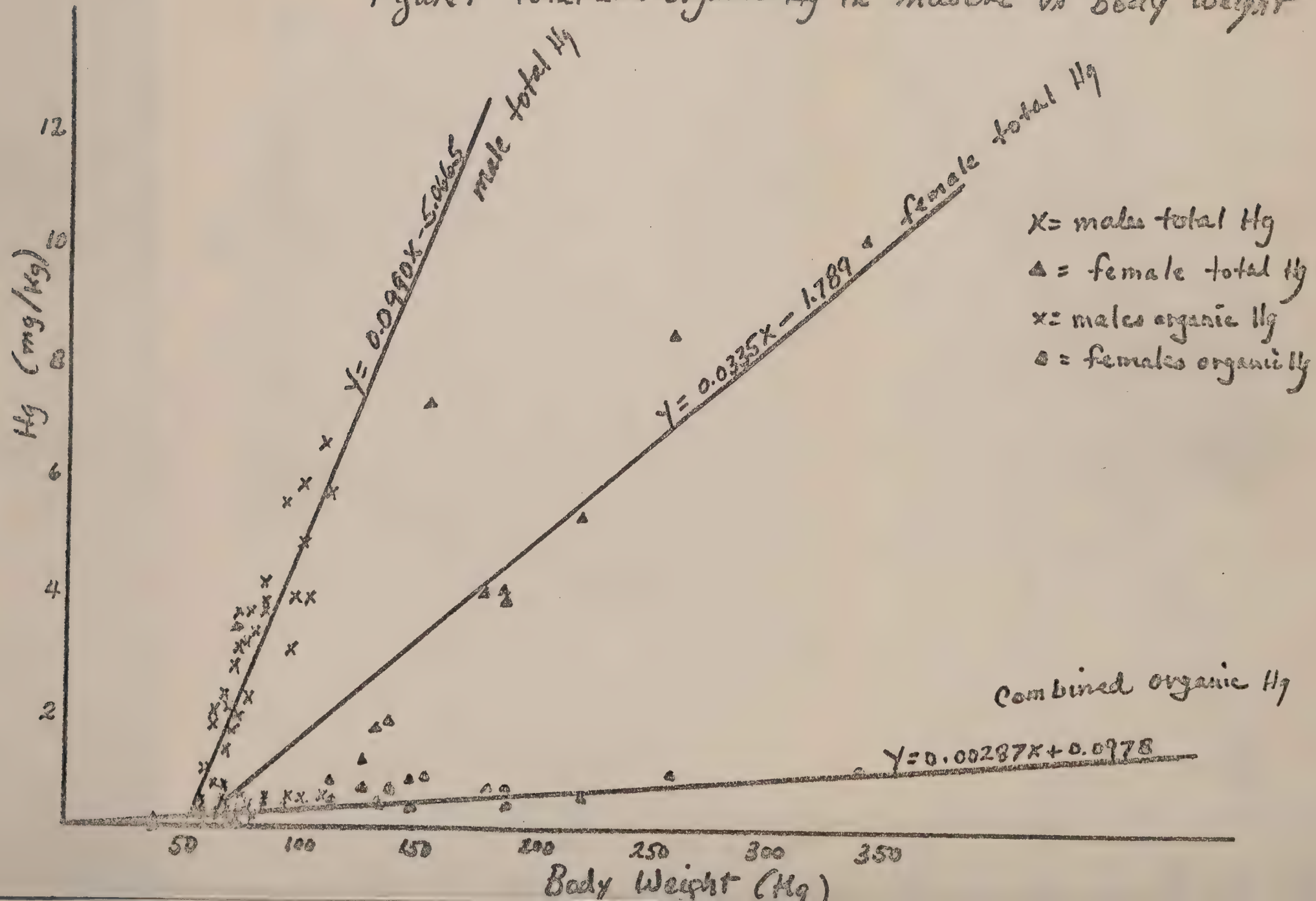
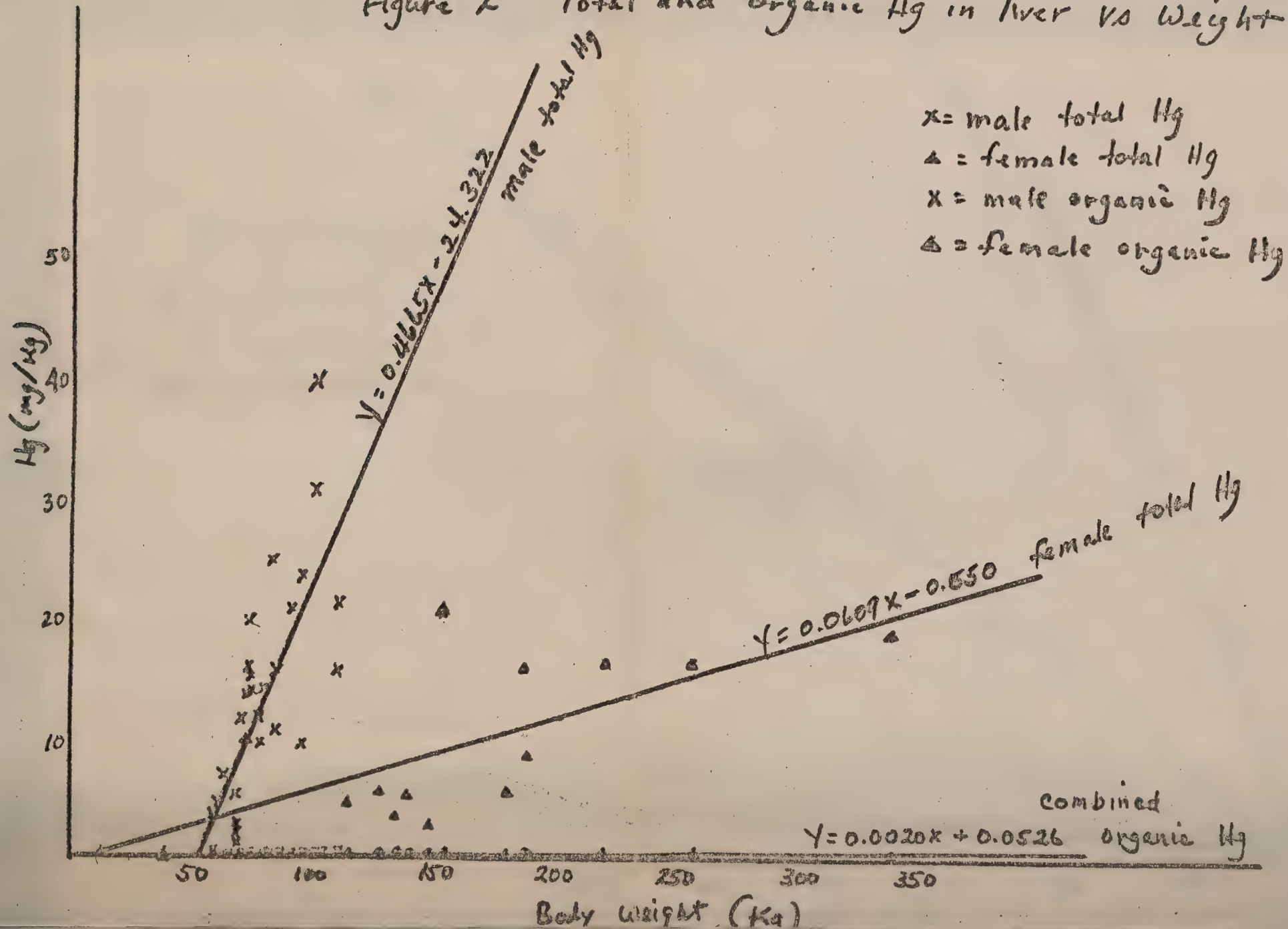


Figure 2 Total and Organic Hg in liver vs Weight





U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southwest Fisheries Center
Honolulu and La Jolla Laboratories
P. O. Box 3830
Honolulu, Hawaii 96812

Reply to Attn. of:

Date: March 28, 1975

To: Richard S. Shomura, Director, Honolulu Laboratory, F142

From: Tamio Otsu, Chief, Tuna Assessment and Development Investigations

Subject: Trip Report: Trip to Japan, January 31-February 22, 1975

My itinerary on this trip to Japan was as follows:

January 31 - 1345, departed Honolulu via PAA 831.

February 1 - 1740, arrived Tokyo.

- 2-9 - In Shimizu, Shizuoka Prefecture. Attended Japanese Tuna Research Conference, visited staff members of Far Seas Fisheries Research Laboratory, Tokai University, Faculty of Marine Science and Technology, eel culture farms in Hamamatsu, and the Shizuoka Prefectural Warm Water Utilization Research Center in Hamaoka City.
- 10-12 - In Kochi City, Kochi Prefecture. Visited with staff members of the Nansei Regional Fisheries Research Laboratory.
- 13-15 - In Tokyo. Visited Federation of Japan Tuna Fisheries Co-operative Associations, Sanyo Hydrographic Survey Co., American Embassy, etc.
- 16-17 - In Sendai. Visited the Tohoku Regional Fisheries Research Laboratory in Shiogama City.
- 18-21 - In Tokyo. Visited the Overseas Fishery Cooperation Foundation, the Japan Marine Fisheries Resource Research Center, Iwatani & Co., Ltd., and met with personnel of the Universal Marine Consultant Co., Nichiro Gyogyo Kaisha, Bumble Bee Seafoods Company, University of Tokyo, etc.
- 22 - 2230, departed Tokyo via PAA 830.
- 1000, arrived Honolulu.

This trip report is arranged by subject matter. The following subjects are covered:

- A. The Japanese Tuna Research Conference
- B. The Japanese tuna fishery, its present dilemma
- C. Purse seining in the western Pacific
- D. Japanese southern water skipjack tuna fishery, July 1974-January 1975
- E. Skipjack tuna fishery survey in Micronesia
- F. Capturing skipjack tuna live bait on the high seas
- G. Bluefin tuna rearing experiments in Japan
- H. Use of live bigeye scad, Trachurus japonicus, as longline bait
- I. Antarctic krill
- J. Unusual abundance of eel (unagi) elvers
- K. Japanese coastal fishermen encounter problems with Soviet fishermen
- L. Miscellaneous
 - 1. Sardines
 - 2. Building boom continues for large skipjack tuna vessels
 - 3. Roback automatic fishing machines
- M. List of persons contacted during trip

A. THE JAPANESE TUNA RESEARCH CONFERENCE

The Japanese Tuna Research Conference is convened each year, generally in February, to bring together representatives of various organizations conducting work on tunas, to discuss the previous year's accomplishments, and to consider plans for future work. It is conducted entirely in the Japanese language, but certain foreign institutions are invited to send representatives. The Inter-American Tropical Tuna Commission (IATTC) and the Southwest Fisheries Center have sent representatives to most of the recent conferences.

The Conference this year was held again at the Chuo Kominkan (Civic Center) of Shimizu City, Shizuoka Prefecture, on February 4-6, 1975. In attendance were about 200 persons representing the tuna industry.

(prefectural and national fisheries cooperatives), national and prefectural fisheries agencies, fisheries high schools, and universities. The IATTC was represented by its Director, Dr. James Joseph, who presented a summary of the work of the IATTC through an interpreter, Dr. Ichiro Yamanaka. The IATTC reports are of interest to the participants since Japan is a member of the Commission. I spoke in Japanese on the results of our project to transport anchovy from California to Hawaii to augment the Hawaiian bait supply and help expand the local skipjack tuna fishery. This talk was well received and generated a great deal of discussion. This was the seventh time I had participated in the annual tuna conference.

B. THE JAPANESE TUNA FISHERY, ITS PRESENT DILEMMA

The Japanese tuna industry this year is facing a major depression, a situation which has developed following the "oil shock" of 2 years ago and the subsequent inflationary trend. The problems are compounded by generally declining tuna longline catch rates and depressed tuna prices. When compared with the "mercury shock" of about 4 years ago, or the "canned tuna decomposition" problem of 3 years ago, both of which caused heavy losses to the tuna industry in Japan, the present situation is considered far more serious. Some sources predict that perhaps as many as 20% to 30% of the tuna longline vessels will soon become inactive, many going into bankruptcy. The problem and causes are complex, but some of the more obvious reasons for the present state are these:

1. Tripling of oil prices in the last year.
2. Increased cost of fishing gear (particularly those oil-related products) and provisions needed for extended fishing operations.
3. Generally declining catch rates throughout the areas of operation.
4. Depressed fish prices in Japan.
5. The virtual closing of the U.S. markets to Japanese exports of albacore, yellowfin and skipjack tunas.

These problems are not restricted to Japan alone; they affect Korea and Taiwan and other tuna fishing nations as well. Korea and Taiwan may be even more affected since their longline vessels fish strictly for the export market, whereas a segment of the Japanese longline fleet fishes primarily for the domestic sashimi market. This is not to say that vessels fishing for the domestic market are not also having their problems at this time.

The increased oil prices, having gone from \$40 to \$50 per ton a year or so ago to the present \$110-\$130 per ton, have resulted in a daily

fuel cost of more than \$400 for vessels that burn about 3.5 tons of fuel per day (e.g. many of the Korean vessels in the 220-280 ton category). Added to this is the high cost of fishing gear and other provisions needed for extended fishing trips. In the meanwhile, catch rates have been declining in all oceans where these longline vessels fish. Reports indicate that catches in some areas have now fallen to less than 1 ton per day of fishing. A recent report from American Samoa shows that albacore catches have fallen far below a ton a day. It is easy to see that ex-vessel revenues of \$500-\$550 per day will not pay for the present high cost of operations.

The longline vessels (Korean and Taiwanese) based in American Samoa have had to extend their fishing grounds farther and farther away from the base. Fishing trips have increased in length to about 6 months for the larger vessels of about 250 tons, while 140-ton vessels are out 3 to 4 months. And still many of the vessels are returning to port with less than a full load. A source believed that about 30 Korean vessels will soon leave American Samoa, probably to return to Korea.

Probably most serious of all is the virtual closure of the American market to Japanese exports of albacore, yellowfin and skipjack tunas. Japanese sources reported that the U.S. canners have built up a large inventory of canned tuna as well as raw materials, and that they are no longer importing tunas from Japan (and presumably from other countries) or are offering prices for these fish that are agonizingly low. They attribute the large inventory to such causes as 1) declining meat prices in the U.S., and 2) bad publicity given "contaminated" canned tuna recently, both resulting in lower tuna consumption in the U.S. Some expressed hope that U.S. consumption of fish would increase during the Lenten Season and U.S. canners would then resume importing.

During my visit the newspapers and weekly magazines in Japan were giving considerable coverage to the financial problems of the Nichiro Gyogyo Kaisha. They reported that poor management had caused the company to overextend its operation to the point of near-bankruptcy. The company president and others in positions of leadership were removed and replaced by bank officials, and many of the executives were demoted in rank. The company reported that tuna and skipjack operations were to be terminated, and that 633 employees connected with this division would be released.

There are 13 Nichiro-owned skipjack tuna fishing vessels based in Tema, Ghana. The company decided to tie up all of the vessels, return the men to Japan, and terminate their employment. Subsequently, however, the powerful Seamen's Union in Japan has apparently forced Nichiro Kaisha to retract these plans (according to a news article dated February 20). One company official told me that these 13 skipjack tuna vessels had been built especially for operation in the waters off West Africa and are not suitable for Japanese waters. They are

built with very low freeboard, and fishermen fish off the sides and stern, but not at the bow as on traditional Japanese skipjack tuna vessels. The disposition of these vessels is a big problem, he said.

The reasons given for the problems encountered in the Ghana operation were 1) low prices offered for skipjack and yellowfin tunas by the U.S. canner; 2) ICCAT regulations setting forth minimum sizes of yellowfin tuna to be taken off West Africa, which make operations difficult; and 3) increased cost of operations. Certainly this must be a simplified explanation of the problems faced by the Nichiro Kaisha, but it points to the generally depressed condition throughout the tuna industry.

During the "mercury shock" when the tuna fishery was faced with plummeting fish prices and decreased consumption, the Federation of Japan Tuna Fisheries Co-operative Associations (Nikkatsuren) did much to ease the problem. The Nikkatsuren carried out an intensive promotional campaign to assist in the recovery. They also purchased considerable amounts of fish, particularly albacore, and held them in freezers to stabilize prices. As a countermeasure to today's problem where Japan is unable to export its fish, Nikkatsuren apparently is planning construction of more freezers in order to purchase and store away the fish until the present situation eases.

Another serious problem faced by the tuna industry (particularly the producers) is that they have no direct control over prices. The depressed prices are attributable, in part, to the import of tunas into the Japanese markets directly by foreign fishing vessels. Vessels from Korea, Taiwan, and those flying the Panamanian flag (but manned mostly by Koreans) are delivering fish to Japanese ports. Such imports of fish amounted to 60,000 tons last year and the amount has increased year after year. This situation is apparently unavoidable under present Japanese law. Because most of these imports are from Korea, negotiations were carried out recently to see if they would limit the amount of tuna delivered directly. The Koreans have apparently agreed to limit the number of vessels delivering directly to Japan to the present 160 vessels, or approximately a third of the Korean longline fleet. No agreement was reached on the amount to be delivered, however.

The foregoing account is based on scattered information provided by numerous sources and some of the statements are unverified. It is certain that the problems facing the Japanese tuna industry are given here in a most simplified form. Nevertheless, the important message is that the people in the industry consider the situation most serious, and that the Japanese word "fukyo" (depression) is most commonly used to describe the Japanese tuna fishery today.

C. PURSE SEINING IN THE WESTERN PACIFIC

For several years now, the Japanese have been sending chartered seiners to the western equatorial Pacific to conduct exploratory purse seining for skipjack and yellowfin tunas. Initially, the Japan Fisheries Agency undertook this work, and it was later carried on by the Japan Marine Fisheries Resource Research Center (JAMARC). It has now come to the stage where the Japanese consider purse seining to be commercially feasible, and several commercial seiners are operating in the western Pacific and in the Coral Sea. Catches are averaging close to 10 tons per set; the vessels are achieving success in catching fish in 80% of the sets made. The average catches are lower than in the eastern tropical Pacific purse seine fishery, but these Japanese seiners are considerably smaller than the average U.S. seiners, most being from 250 to 500 gross tons in size.

The Japanese initially found it extremely difficult to successfully set around the schools as the fish tended to escape before the net could be pursed. They also found that certain types of schools were more difficult to capture than others, and that the time of day seemed to make a great difference. Today, the Japanese believe that they can achieve success under the following conditions:

1. Schools must be associated with drifting objects (driftwood, etc.).
2. Sets must be made either early in the morning or at dusk.
3. Nets must be larger than those used in the eastern Pacific.

Consequently, the fishing masters on the seiners constantly search for drifting objects and associated schools, and when such a school is found they often follow it until early morning, tracking it overnight by marking the drifting object with radio buoy and lights, or dusk before making their set.

The purse seine nets used in the western equatorial Pacific (area north of Papua New Guinea) and in the Coral Sea are larger than those used in the eastern Pacific. The following examples of net sizes are provided:

<u>Vessel</u>	<u>Area used</u>	<u>Size of net</u>
<u>Nippon Maru</u>	Eastern Pacific and West Africa (U.S.-type seiner)	110 m deep x 1,025 m long or 118 m deep x 1,350 m long
<u>Hayabusa Maru</u>	North of Papua New Guinea	220 m deep x 1,600 m long
<u>No. 58 Tokiwa Maru</u>	North of Papua New Guinea	250 m deep x 1,960 m long

<u>Vessel</u>	<u>Area used</u>	<u>Size of net</u>
<u>No. 55 Hakuryu Maru</u>	Japan coastal waters for skipjack and yellowfin tunas	150 m deep x 1,500 m long or 220 m deep x 1,500 m long
<u>Wakaba Maru</u>	do.	220 m deep x 1,500 m long
<u>No. 23 Taikei Maru</u>	do.	200 m deep x 1,500 m long
<u>No. 28 Kohoku Maru</u>	do.	261 m deep x 2,025 m long
<u>No. 85 Seishin Maru</u> (two-boat seining)	do.	350 m deep x 1,700 m long
<u>No. 7 Konpira Maru</u> (two-boat seining)	do.	240 m deep x 2,400 m long

The results of the most recent charter cruises were reported by JAMARC as follows:

Vessel: Fukuichi Maru, 500 tons
 Survey area: Around the Caroline archipelago
 Survey period: June 18-November 30, 1974

First cruise

Departed Yaizu on June 20. Started survey southward beginning around the Bonin Islands, and worked as follows: June 24-25, south of Hahajima; July 1-8, west of the Carolines at 6°-7°N, 141°-143°E; July 9-15, east of Palau; July 16-August 2, southeast of Palau at 3°-4°N, 136°-138°E; August 7-16, Western Carolines at 4°-6°N, 142°-147°E.

Made a total of 27 sets and caught 229 tons of skipjack tuna, and 53 tons of yellowfin tuna for a total of 282 tons. The catch per set amounted to 10.4 tons; the maximum catch was 32 tons per set. A full load was obtained on August 16 so the survey was terminated and the vessel returned to Yaizu.

Second cruise

Fukuichi Maru departed Yaizu on September 2 en route to fishing grounds. Started fishing in waters southeast of Palau. Fishing was not as good as on the earlier cruise. Worked in area 0°-8°N, 135°-145°E, and on October 7 arrived in Guam, where they unloaded 22 short tons of skipjack tuna. Only 10 sets had been made for a catch of 22 tons of skipjack tuna and 33 tons of yellowfin tuna, a total of 55 tons.

Third cruise

Fishing commenced on October 12 in the area 4°-8°N, 145°-151°E (eastern Carolines). Three sets resulted in 18 tons of fish. In waters south-east of Palau at 2°-5°N, 140°-145°E, 14 sets resulted in 127 tons of fish. Up to this point, fishing conditions were as poor as on second cruise. Only two sets had resulted in about 10 tons per set; others were in the order of 1 to 3 tons per set. However, toward the end of the survey period, on November 6, a catch of 20 tons was made at 2°N, 144°E. Since it looked as though fishing would improve after this, the cruise period was extended. The vessel fished until November 18 and returned to Yaizu on November 26.

During the charter period, the Fukuichi Maru fished 53 schools associated with drifting objects, and caught 168 tons of yellowfin tuna, 320 tons of skipjack tuna, and 12 tons of miscellaneous species, for a total of 500 tons. The target catch of 468 tons was exceeded by 32 tons.

According to JAMARC, there are now five or six commercial seiners working in the Coral Sea (15°S, 147°E) for yellowfin tuna.

The average catches as well as the success rate of seining in the western equatorial Pacific must be considered in the light of fishing effort. If vessels avoid making sets during midday, this cuts down fishing effort considerably. The size of the seiners (small relative to U.S. seiners) may be the saving grace in this particular fishery.

Because Japanese seiners are so completely dependent upon drifting objects in order to make successful sets on skipjack and yellowfin tunas in the western equatorial Pacific, Japanese researchers would like to develop artificial drifting objects that will aggregate tunas for seining. Studies have already indicated that there is promise in this approach.

- D. JAPANESE SOUTHERN WATER SKIPJACK TUNA FISHERY, JULY 1974-JANUARY 1975 (From a preliminary report prepared by Mr. Tamotsu Tanaka, Yaizu Branch, Tohoku Regional Fisheries Research Laboratory.)

July-August 1974 (See corresponding charts.)

Because fishing was poor in the Marianas area, many of the larger vessels (larger than 299 tons) went south and fished around lat. 3°-6°N, long. 143°-158°E, as well as around lat. 1°N, long. 168°-173°E. Initially, the catches ranged from 3 to 20 tons per day, averaging between 5 and 7 tons, with considerable variation from vessel to vessel. The first part of August the fishing grounds east of long. 160°E became very unproductive. Vessels shifted westward to lat. 2°-6°N, long. 145°-155°E, where fishing was somewhat better; there some

vessels took more than 30 tons per day. However, results were mixed, and the fishing condition was generally unstable. Of the skipjack tuna taken, 70%-75% were 3-4 kg fish.

At the end of the albacore season, there were vessels which ventured eastward from the Emperor Seamount towards the Hawaiian Islands. These vessels reported maximum catches of 20-25 tons per day, but average catches were between 7 and 8 tons (including small yellowfin tuna). In this area (Northwest Hawaiian Islands) large skipjack tuna of 9-15 kg are usually quite abundant, but this year such large fish were few and about 70% of the catch consisted of 1.5-4.0 kg fish.

In August, there were 50-60 vessels fishing in southern waters and about 20 vessels operating near the Northwest Hawaiian Islands. The landings of southern water fish at Yaizu during July-August were as follows:

July.--Twelve vessels unloaded 751.4 tons; the average landings per vessel amounted to 62.6 tons (including 17.9 tons of small yellowfin tuna). From the waters around the Northwest Hawaiian Islands, four vessels unloaded 721.8 tons, averaging 180.4 tons per vessel (including 101.1 tons of small yellowfin tuna).

August.--Sixty-one vessels unloaded 5,675.5 tons (including 99.9 tons of small yellowfin tuna), averaging 93.0 tons per vessel. One purse seine vessel unloaded 192.2 tons of skipjack tuna and 83.5 tons of small yellowfin tuna. From the waters near the Northwest Hawaiian Islands, six vessels delivered 655.0 tons (including 55.9 tons of small yellowfin tuna); the average landing per vessel amounted to 109.1 tons.

September 1974

In September, most of the vessels over 299 tons shifted to the southern water skipjack tuna fishery and the fishing grounds expanded widely in an east-west direction. There were 130-140 vessels in the fishery. Fishing continued to be poor, with daily catches of 2-15 tons, averaging around 4 tons per day. The waters south of the equator were scouted but no good fishing grounds were located. Although fishing conditions had been poor since July, considerable numbers of fish schools (with bird flocks) were reportedly being seen in waters west of long. 145°E to the vicinity of Palau. However, the fish were poor-biting, and the maximum catches were 7 or 8 tons per day. The average catches amounted to around 3 or 4 tons per day. As in July-August, the fish sizes were 3 or 4 kg for the most part. In the vicinity of the equator as well as in waters west of long. 145°E, fish of 1.5-2.0 kg generally make up 10% to 20% of the catch. This year, however, such small fish were reported to be very scarce.

The water temperatures in the fishing grounds west of long. 150°E were 29.5°-30.7°C, higher than usual by 0.5°-1.0°C. In these higher temperatures, the baitfish suffered considerable mortality. In most years, the vessels report some baitfish mortality around lat. 20°N when encountering high water temperatures. However, the survival is usually good thereafter, and the remaining baitfish can be used on the fishing grounds. This year, however, the high temperatures on the fishing grounds appeared to have caused additional mortality. Many vessels reported mortalities greater than 60%. As a result, the tuna catches were also poor, and many vessels returned to port with less than 50 tons of fish. Even those vessels that managed to maintain their baitfish supply encountered such poor fishing that they had to spend 26-30 days on the fishing grounds, thus extending the trip to 35-45 days.

In September, 50 vessels unloaded 4,310.6 tons of fish at Yaizu for an average delivery per vessel of 86.2 tons (including 111.5 tons of small yellowfin tuna). One vessel returning from east of the international date line delivered 106.5 tons (including 14.5 tons of small yellowfin tuna).

October 1974

The fishing grounds in October extended broadly from the Caroline Islands to the northern part of the Solomon Islands. In all areas, vessels reported seeing considerable numbers of fish schools. However, the fish were not responding well to chumming and catches were poor. Throughout the Caroline Archipelago, the water temperatures were higher than usual by 1.0°-1.5°C, being reported at 29.5°-31.0°C. There were many reports of heavy baitfish (anchovies from Japan) mortality, a condition that first started in September. The effect of temperature on baitfish was being felt by all vessels that had gone to southern waters at the end of the albacore season in Japanese coastal waters.

Many vessels fished in the area bounded by lat. 3°-6°N, long. 136°-145°E in early and mid-October. Towards the end of the month the effort shifted to the waters north of the Solomon Islands (lat. 0°-3°S, long. 150°-156°E). The catches improved some, but there was still considerable variation among vessels, and fishing conditions continued unstable. Only a few vessels returned to port with catches exceeding 100 tons. In early and mid-October, the maximum catches were reported to be 10-15 tons per day, averaging 3-4 tons per day; towards late October, the maximum catch was 32 tons, averaging 5-6 tons per day. The skipjack tuna ranged in weight from 1.8 to 3.5 kg, and averaged 2.5 kg. There were about 120 vessels fishing in southern waters during the month.

The fishing grounds in the waters extending from the Gilbert Islands to the Marshall Islands, usually good at this time of the year, turned

out to be very poor this year. Fishing was particularly poor in the Marshall's north of lat. 8°N , where schools were reportedly very scarce. In waters south of lat. 7°N , fish schools were also scarce but were better biting and catches of 7-10 tons per day were reported. There were 10-15 vessels in the Gilberts-Marshall's area.

On the other hand, vessels fishing east of the international date line reported good catches of 18-32 tons per day. The water temperatures in the area ranged from 28.5° to 29.2°C . The fish sizes ranged from 3 to 7 kg.

In late October, two skipjack tuna vessels went to the Coral Sea to handline for tunas. These vessels caught 60 tons and 18 tons, respectively, of bigeye and yellowfin tunas. Two purse seiners in the Coral Sea reported taking a total of 200-250 tons of tunas.

In October, 96 vessels delivered a total of 7,913.3 tons of fish, averaging 82.4 tons per vessel. At the same time last year, 83 vessels landed 10,874.8 tons, averaging 131.0 tons per vessel.

November 1974

Within the area bounded by lat. 2°S - 5°N , long. 141° - 146°E , the northern and southern boundaries provided good fishing and many of the vessels began shifting their efforts accordingly. The maximum day's catch was reported at 30 tons; the average catch was around 4-5 tons per day in both areas. The skipjack tuna were 2-6 kg in size. Most of the 35-40 vessels fishing there were large.

In the vicinity of the Gilberts at lat. 1° - 2°S , long. 172° - 174°E , good fishing occurred for a very short time. Soon thereafter, good fishing was reported at lat. 4°N , long. 168° - 169°E , where toward late November catches of 30 tons were reported. There were 50-60 vessels in the vicinity.

Some vessels worked farther to the east of the international date line than they had in October, and reached the vicinity of lat. 5° - 6°N , long. 163°W . But they fished mainly around lat. 5° - 7°N , long. 168° - 171°W where the water temperatures were 28.2° - 28.3°C . Maximum catches were around 50 tons per day. The size composition of the skipjack tuna was as follows: larger than 6 kg, 24%; 4.5-5.9 kg, 72%; 2.5-4.4 kg, 4%. Thus, virtually all of the fish were large, weighing more than 4.5 kg.

A vessel entering the port of Makurazaki reported sighting numerous large schools of very small skipjack tuna (around 10 cm long).

In late November, the No. 3 Inasa Maru from Tago in Shizuoka Prefecture and three other vessels caught considerable amounts of doku-uroko.

ibodai, Tetragonurus atlanticus, around a night light at lat. 3°N, long. 161°E, where the water temperature ranged from 29.0° to 29.4°C. Using this "high seas" baitfish, the vessels experienced good results in skipjack tuna fishing. This is probably the first time that baitfish has been taken in quantity on the high seas in southern waters. It is desirable to conduct detailed studies on this potential baitfish resource in the future.

December 1974

Five separate fishing grounds developed during the month as follows:

1. Lat. 9°-17°N, long. 130°-135°E

Most of the vessels fishing in this area were from Kagoshima Prefecture, but a few were from Mie Prefecture. In early December, the main ground formed at lat. 17°N, long. 133°-134°E. The ground gradually shifted southward. Later in the month it was at lat. 9°-10°N, long. 131°-133°E. The maximum catch amounted to 20-25 tons and the average was around 7 or 8 tons per day. Fishing conditions were stable; the skipjack tuna weighed 5-6 kg. There were about 30 vessels in the area.

2. Lat. 2°S-5°N, long. 139°-145°E

In this area, the fishing grounds formed along the northern and southern borders similar to the previous month. Fishing was rather poor with a maximum catch of 25-30 tons per day and an average catch of 4 or 5 tons per day. Fish schools were reportedly numerous, however. As for fish sizes, the skipjack tuna taken along the southern border weighed 3-5 kg; those along the northern border were 3-6 kg. The fish along the southern border were somewhat larger than in other years.

3. Lat. 3°-6°N, long. 164°-170°E

There were 30-40 vessels fishing this area; the average catch amounted to 4-5 tons per day. The maximum catches were around 18-20 tons per day. The skipjack tuna weighed 3-6 kg.

4. Lat. 5°-8°N, long. 172°-176°W

The water temperature in the area was 28.0°-28.3°C. Fishing continued to be poor through mid-December. There were 15-20 vessels venturing eastward to this area. Towards late December, the catches reached about 20 tons per day. The vessels reported winds of force 3 or 4 in the area. Some experienced rather good fishing and five or six vessels returned to port with full loads. The skipjack tuna size composition was as follows: larger than 6 kg, 2%; 4.5-5.9 kg, 51%; 2.5-4.4 kg, 43%; 1.5-2.4 kg, 1%.

5. Lat. 7°-9°S, long. 150°-155°E

The water temperature in this area (Solomon Sea) was 29.1°-30.0°C. Fishing grounds developed about 2 months earlier than in previous years but catches were poor, with a maximum of 20 tons per day and an average catch of 4 or 5 tons per day. The skipjack tuna weighed 1.5-3.5 kg; there were five or six vessels fishing this area.

January 1975

Fishing grounds developed in four locations:

1. Lat. 7°-9°S, long. 150°-155°E

The water temperature in this area (Solomon Sea) was 29.2°-30.0°C. Through mid-January, the catches were exceedingly poor, with vessels reporting catches of 3-5 tons per day. In late January, the fishing improved and catches of 10-20 tons per day were seen here and there. Numerous reports were received of schools associated with whale sharks. Fishing such schools, the proportion of small yellowfin tuna and small bigeye tuna of 3-7 kg increased to 5% to 10% of the total catches.

The skipjack tuna size composition was as follows: larger than 4.5 kg, 5.5%; 2.5-4.4 kg, 55.5%; 1.5-2.4 kg, 39%. There were 30-40 vessels fishing the area.

2. Lat. 2°S, long. 152°-160°E

Water temperature in the area was 29.2°-29.5°C. Most of the schools were associated with bird flocks. Catches averaged around 5 or 6 tons per day, with a reported maximum catch of 25 tons. In late January, catches improved to around 8-13 tons per day and fishing conditions continued to be rather stable. The skipjack tuna were mostly (80% to 90%) between 3.0 and 3.5 kg. There were 30-40 vessels in the area.

3. Lat. 8°S, long. 161°-163°E

The water temperature was reported to be between 29.0° and 29.5°C. in this area located north of Guadalcanal. In late January, the catches averaged 7-8 tons, and the maximum reported was 20 tons per day. Some vessels moved to this area from farther west, until there were 10-15 vessels fishing here. The skipjack tuna taken were 3.0-3.5 kg in size.

4. Lat. 6°N, long. 175°-177°W

The water temperature was 27.0°C. Weather conditions were unfavorable with winds of force 3-4 prevailing. In late January, catches were up to 30-49 tons in some cases and three vessels returned home with total catches of 190-220 tons. The skipjack tuna size composition was: larger than 6 kg, 17%; 4.5-5.9 kg, 62%; 2.5-4.4 kg, 20%; and 1.5-2.4 kg, 2%. There were around 20 vessels fishing this area.

In general, fishing conditions during the July 1974-January 1975 period were quite poor throughout southern waters as compared with the previous year. The reasons can be partially attributed to heavy bait mortalities, at least during September and October 1974. Furthermore, though vessels reported sighting numerous schools, they found the schools generally "poor biting."

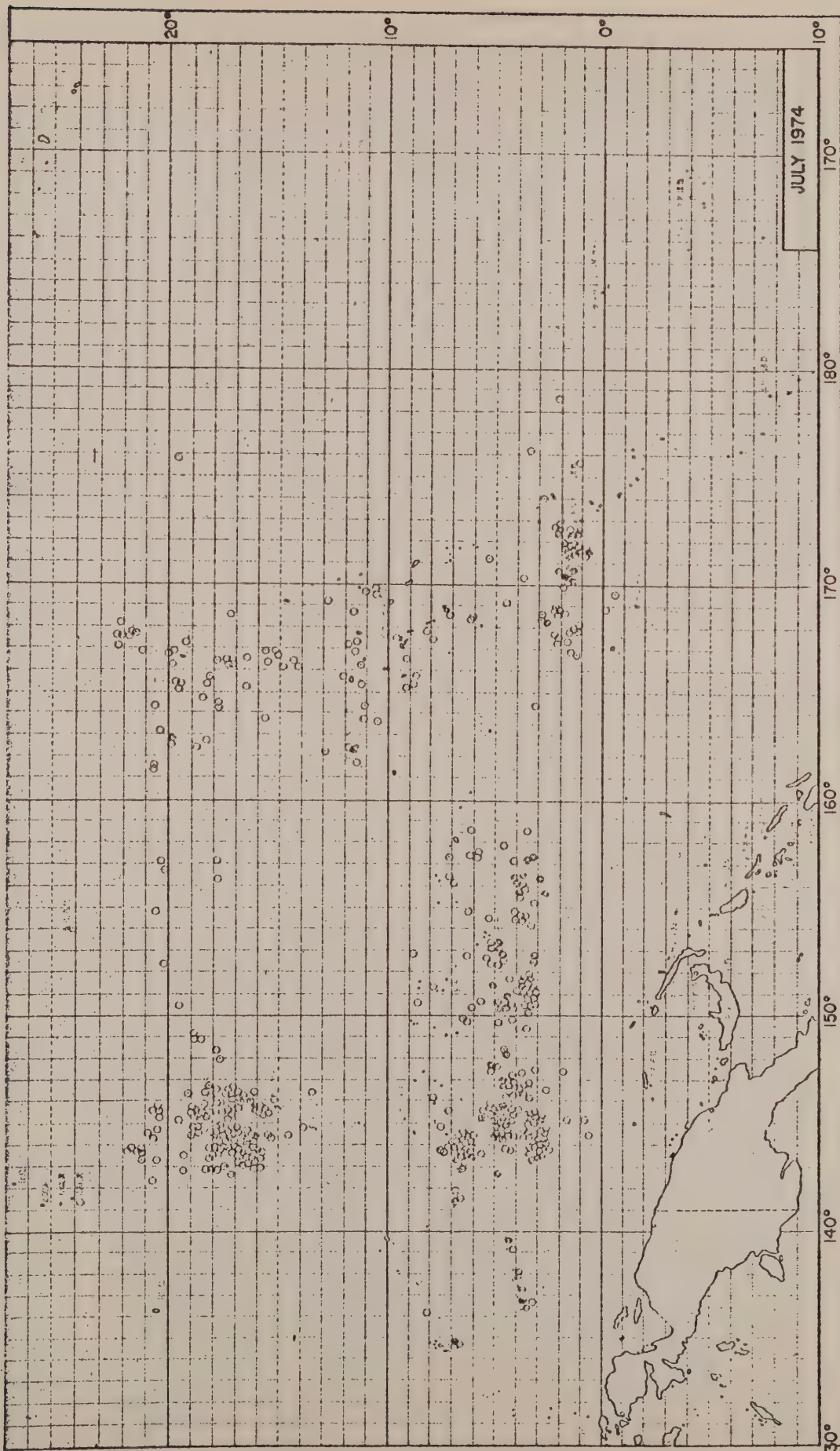
E. SKIPJACK TUNA FISHERY SURVEY IN MICRONESIA

For the last several years the Japan Marine Fisheries Resource Research Center (JAMARC) has been conducting skipjack tuna fishery surveys in various places in the Pacific. In 1972 and 1973, JAMARC sent a chartered skipjack tuna fishing vessel to survey the waters of New Hebrides, New Caledonia, Nauru, Tonga, and Wallis Islands. The results were generally poor, as I reported in last year's trip report. JAMARC concluded that of the various islands surveyed for live bait and for skipjack tuna fishing, New Caledonia held the greatest potential. The insufficiency of baitfish was generally the principal problem. Even in New Caledonia, JAMARC researchers found baitfish to be rather scarce.

In 1974 JAMARC chartered the No. 20 Akitsu Maru, a 190-ton skipjack tuna vessel, to survey Micronesian waters. The survey period extended from July 1 through October 15, 1974. The following is the report on the charter cruise:

The vessel departed Kurihama on July 4 and fished for 6 days in waters between the Bonin Islands and Saipan. Fishing was poor and the catch totaled only 8 tons. The vessel entered the ports of Saipan (July 15-19) and Truk (July 22-24) and discussions were held with local authorities regarding the fishery survey of the Truk area. However, no definite agreement could be reached so the survey of Truk was temporarily suspended.

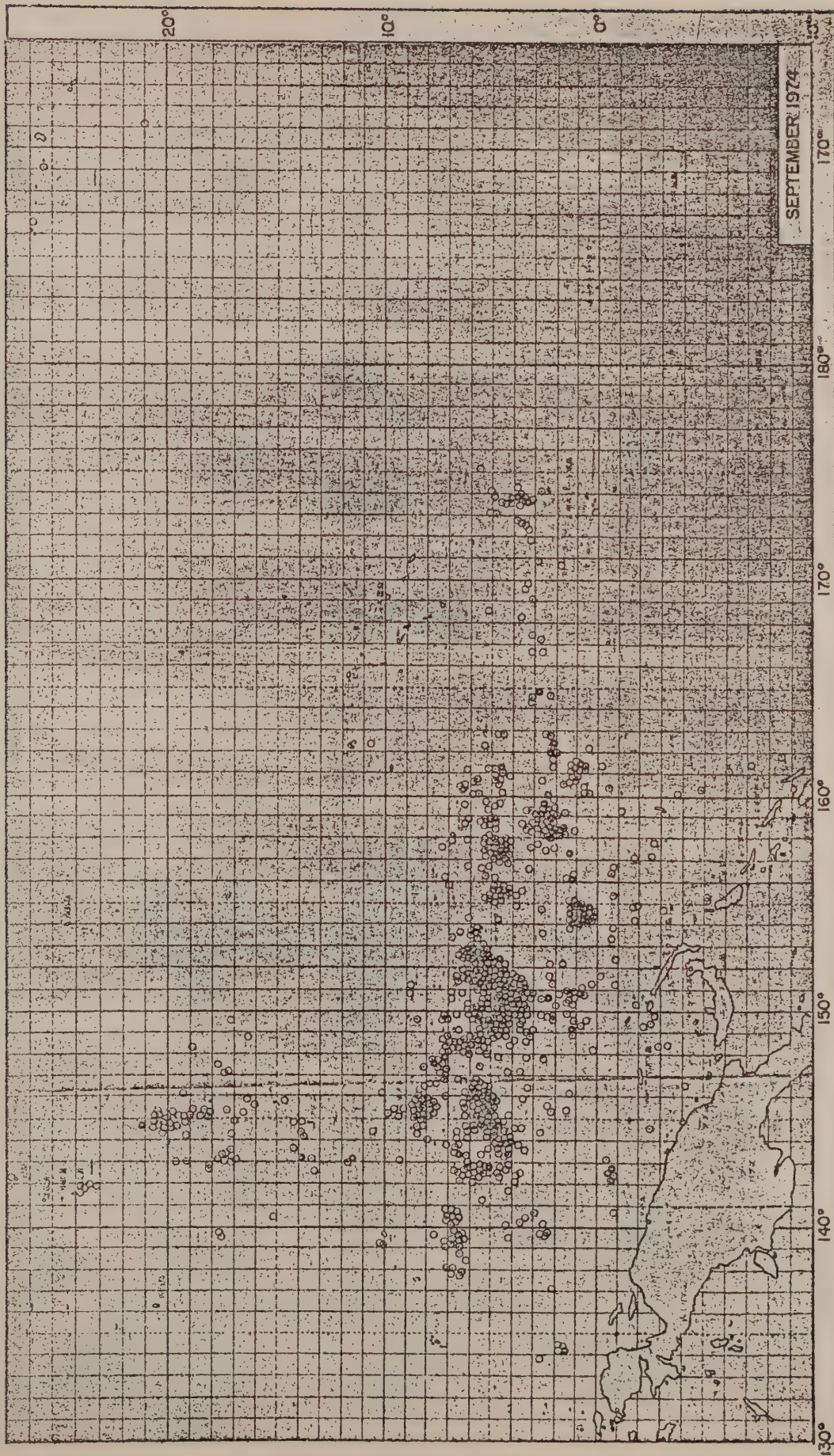
On July 26, the vessel entered Ponape, and again the officers met with local authorities. Here, the local authorities were quick to agree on the survey plan. The survey of Ponape was conducted between August 5 and October 5 following the successful negotiation.

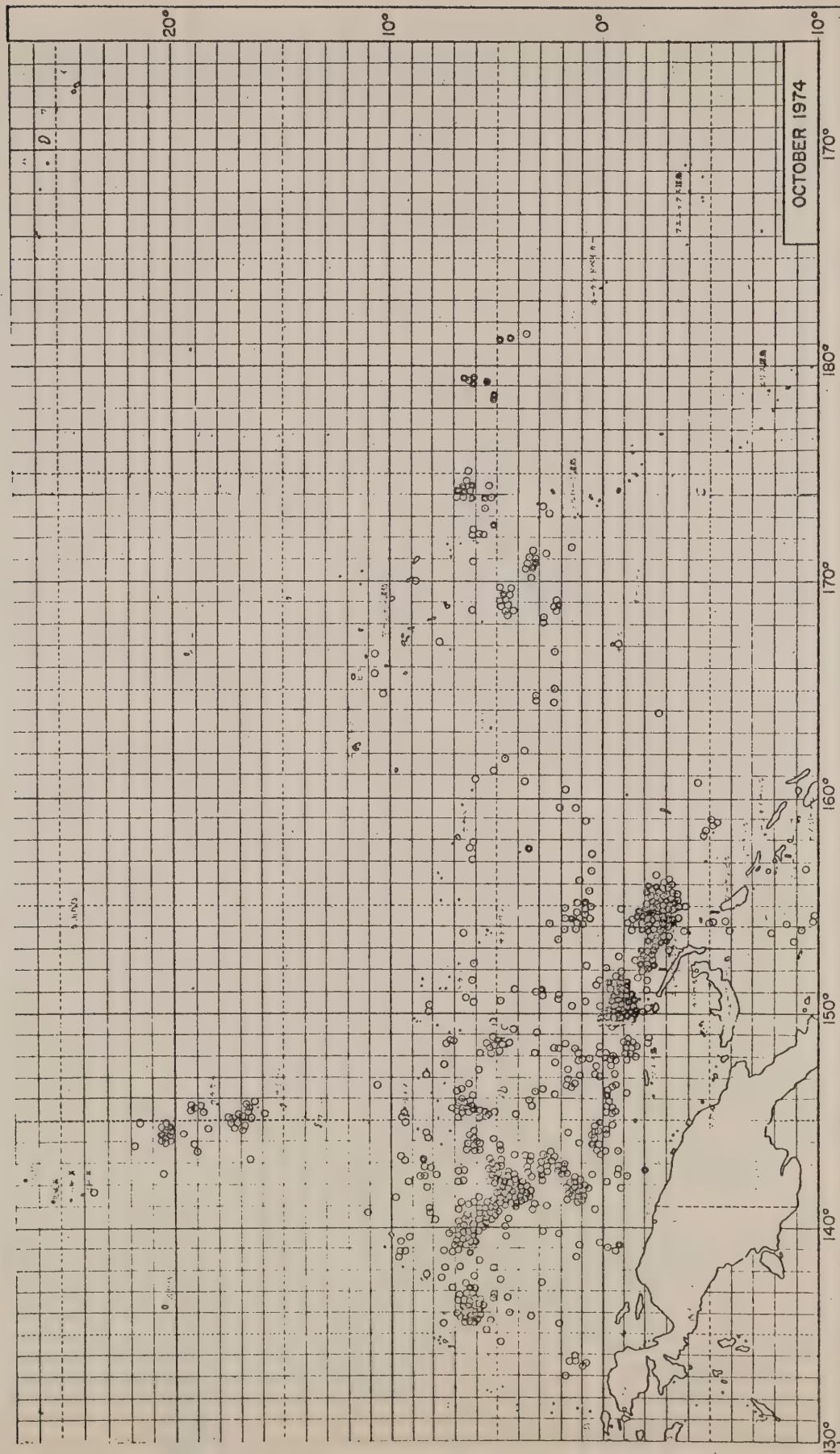


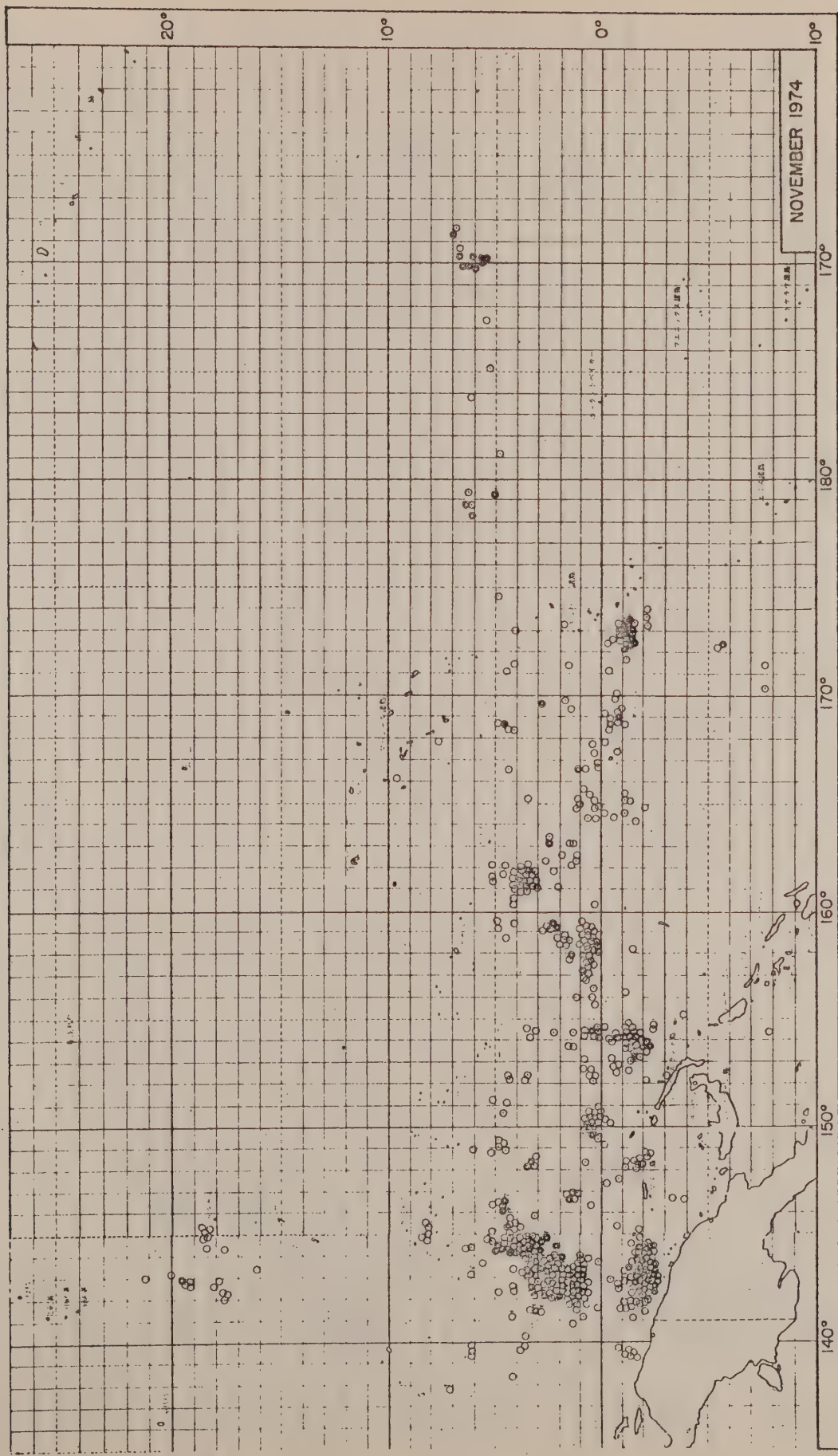
JULY 1974



AUGUST 1974







NOVEMBER 1974

170°E

180°

170°

160°

150°

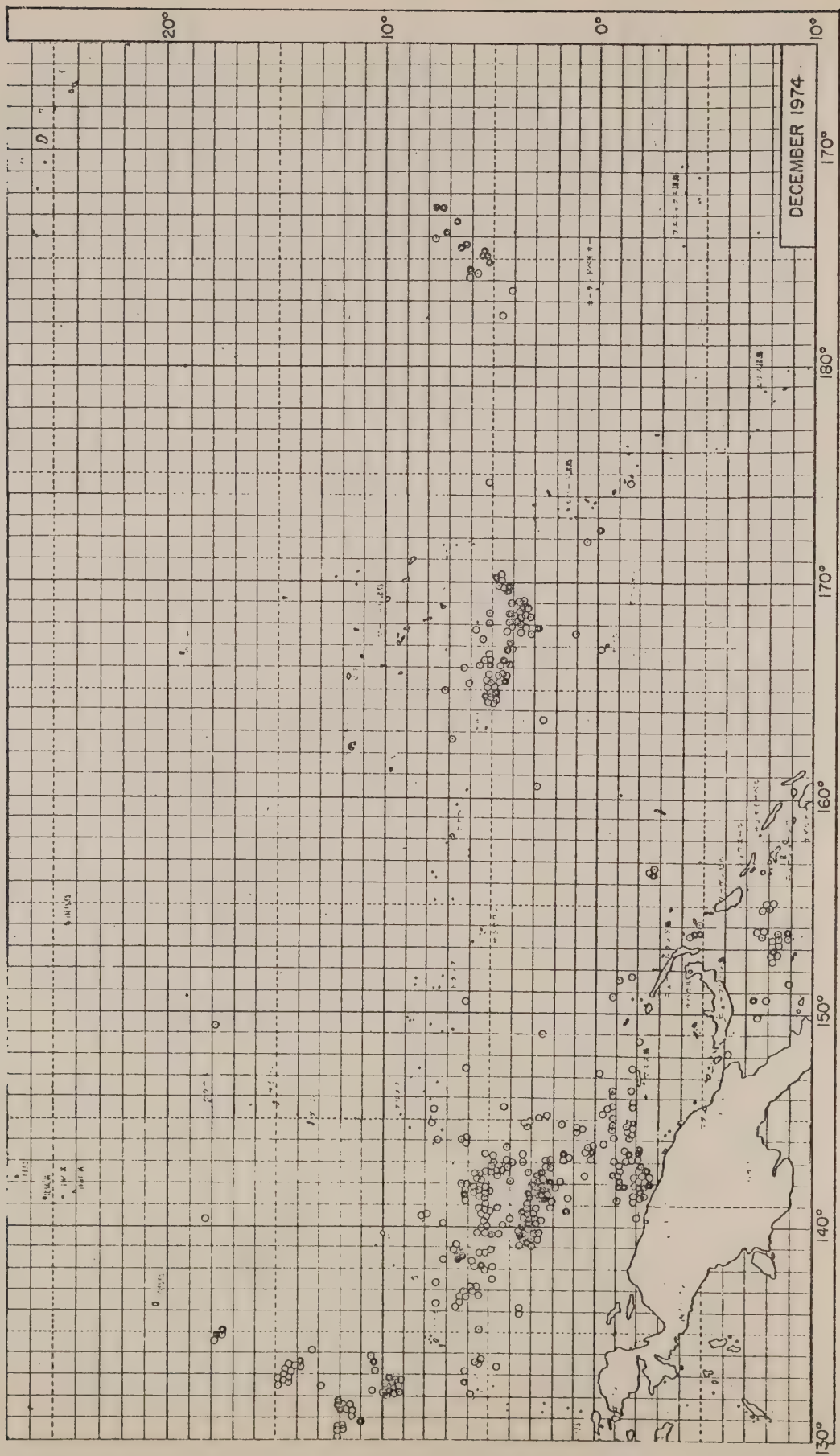
140°

20°

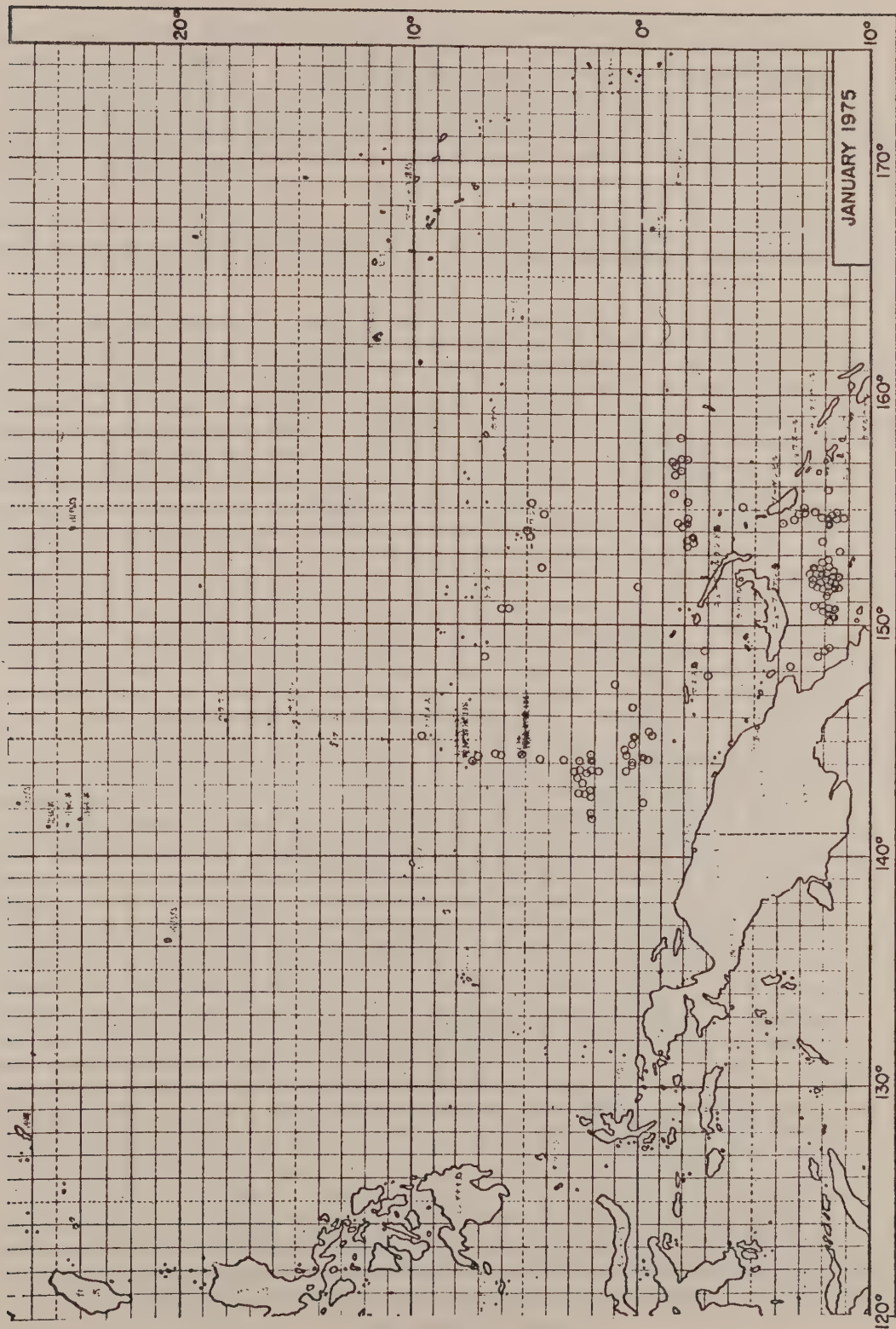
10°

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DECEMBER 1974



A bait survey was conducted by sampling with a stick-held dip net (bo-uke ami) 79 times, beach seine 10 times, and drive-in net (oikomi-ami) 8 times. The most successful method was the use of the stick-held dip net at night on baitfish attracted to a night light. A total of 1,056 buckets of baitfish such as engraulids, clupeids, and atherinids (3 kg per bucket) were taken. The beach seine during the day caught 13 buckets, mainly of carangids and engraulids. The drive-in net, which is considered a difficult bait-catching method, resulted in only one bucket of baitfish. The latter method is used to catch reef-fish such as apogonids.

Skipjack tuna fishing was conducted over 34 days during which 116 schools were fished for a total catch of 34 tons of skipjack tuna, and 0.2 ton of yellowfin tuna. The results were disappointing since the cruise target had been set at 105 tons. Observers cited the following reasons for the poor showing: Bait was scarce and sufficient quantities could not be taken. This often precluded the vessel from fishing during the best hours of early morning and late afternoon. Furthermore, some of the baitfish (anchovies in particular) were very weak, some were stronger but too scarce (clupeids), and some, although rather plentiful and strong, were too large in size (carangids).

JAMARC officials reported that they have received excellent cooperation from local officials and that they are being asked to continue the survey in Micronesia.

F. CAPTURING SKIPJACK TUNA LIVE BAIT ON THE HIGH SEAS

The well-being of the skipjack tuna pole-and-line fishery is dependent to a very large degree on how well and how long live bait can be maintained aboard the fishing vessels. For example, from 1973 to early 1974, the long-ranging skipjack tuna vessels were returning to Japan from southern waters with full loads of skipjack tuna, one vessel after another. However, beginning in the summer of 1974, perhaps due to unusually high water temperatures, the vessels began to experience heavy bait mortalities. Vessels began to report bait mortalities of 30% to 70%, and many vessels returned to port with very small catches.

Because live bait is so vitally important, the Mie and Shizuoka Prefectural Fisheries Experimental Stations have been devoting considerable effort toward the problem of maintaining baitfish on skipjack tuna vessels. They have worked on various approaches (as I have reported on some of my past trip reports) but the problems are far from solved at this time.

Because of the importance of live bait, however acquired, in skipjack tuna fishing, a recent occurrence created considerable stir among the industry people. A skipjack tuna vessel from Shizuoka Prefecture reported catching baitfish on the high seas. The No. 3 Inari Maru

(299 tons), at 3°51'N, 161°15'E, managed to capture 50-60 buckets (3 kg per bucket) of a fish the Japanese call doku-uroko ibodai, Tetragonurus atlanticus, that had gathered around the light of a 500-W lamp. The location was the eastern Carolines, about 180 miles south of Ponape. Using this baitfish, the vessel managed to capture 10 tons of skipjack tuna.

When informed of this, two other vessels from Shizuoka Prefecture, the Tagoshima Maru (299 tons) and the Yasufuku Maru (299 tons), also managed to catch this baitfish in the same general location.

Researchers believe that these fish, coal black in color, probably inhabit deep water. They were 4-7 cm in length and appeared to be a very satisfactory live bait for skipjack tuna fishing. They swam slowly at the surface when chummed and were readily fed upon by the tuna. Furthermore, it was possible to maintain these fish in bait-wells at least up to 16 days. The Japanese reported the need to study the distribution of these fish, their seasonality, and whether or not they can be taken in reliable quantities to further skipjack tuna fishing in southern waters.

G. BLUEFIN TUNA REARING EXPERIMENTS IN JAPAN

A program of "tuna culture and rearing" was financed by the Japan Fisheries Agency in 1970 with national, prefectural, and university laboratories involved in a cooperative effort. The lead agency was the Far Seas Fisheries Research Laboratory in Shimizu. This was a 3-year program which ended in 1973. However, before its termination, considerable progress had been made. Many of the species of tuna were successfully fertilized artificially, eggs hatched, and the larvae reared to a certain size. Tunas were also reared from young taken in the wild. This was the case with the bluefin tuna: young fish taken in traps or by surface trolling in coastal waters were held in net enclosures, fed, and reared for as long as possible. Originally, the difficult problem was to get the captive fish to feed during the cold winter months. Thus, the first hurdle was to "over-winter" the fish while maintaining some growth. The heavy mortality with the onset of cold temperatures remained a major problem. Nevertheless, several of the research facilities reported various degrees of success in this effort.

Although the Kochi Prefectural Fisheries Experimental Station in Kochi, Shikoku Island, was not part of the original program, researchers there are also conducting rearing experiments. Kochi is ideally located for this project since winter temperatures do not fall below 15°C. Bluefin tuna generally cease feeding when temperatures go below 15°C. The rearing facility is located in Komame, Kochi Prefecture, near the southwestern tip of Shikoku Island. Komame is bathed by the warm waters of the Kuroshio, and the bay is blessed with an excellent circulation of clean oceanic water.

Young fish are captured by surface trolling or in traps generally during the latter half of the year. Fish smaller than 0.3 kg are found to be the hardest for rearing purposes. The young fish are placed in the kowari (net enclosures) set up in the bay at Komame. They begin to feed in 3-7 days. The kowari is octagonal in design, 4.2 m to a side, 6 m deep. In general, growth of bluefin tuna is found to be very rapid. The fish grow from 0.1-0.2 kg to 2.5-3.0 kg in 6 months and to 10 kg by the end of the second year. The growth after the second year is estimated at 25-30 kg by the end of the third year, and 40 kg by the end of the fourth year.

The researchers reported that bluefin tuna rearing has a big advantage over yellowtail rearing (the latter is carried out commercially on a rather large scale in Japan). For example, they noted that bluefin tuna growth rate is much faster than yellowtail growth. Also, conversion of food to body weight is better in the case of the bluefin tuna (it was reported that 6 kg of food adds 1 kg of body weight in bluefin tuna whereas it requires 8 kg of the same food to add 1 kg of body weight in yellowtail). Both fish are fed on mackerel, sardines, and the like.

Organoleptic taste tests have shown that bluefin tuna reared for 2 years were very similar in flavor and overall quality to fish taken in the wild, although fish reared only for 1 year were found wanting in flavor. The biggest advantage to bluefin tuna rearing is that they can be marketed at about 4 times the market price for yellowtail. Test marketing has shown that there is ready acceptability of fish reared for more than 2 years.

Although many fishermen who are now rearing yellowtail are beginning to show considerable interest in bluefin tuna rearing, many problems remain before the latter can be made commercially feasible. Unlike yellowtail, no large quantities of young bluefin tuna can now be taken to start a commercial rearing operation. Another problem is that bluefin tuna require much better quality oceanic water than do yellowtail. They are more readily susceptible to mortality from heavy run-offs or deteriorating water quality in the rearing area. In spite of these problems, the Japanese are optimistically looking to the day when commercial rearing of bluefin tuna, and perhaps other high quality tuna species, becomes a reality.

H. USE OF LIVE BIGEYE SCAD, TRACHURUS JAPONICUS, AS LONGLINE BAIT

Last year I reported on the use of live bigeye scad as longline bait in Oita Prefecture. In discussing this matter with researchers of the Nansei Regional Fisheries Research Laboratory, I learned that longline vessels of Kagoshima, Miyazaki, and Kochi Prefectures also use live bigeye scad as bait. These are the smaller coastal longline vessels, mostly under 20 tons.

Apparently, the fishermen of Miyazaki Prefecture were the first to use live bigeye scad in longlining. They began experimenting with this live fish as longline bait in experimental fishing for the dolphin, Coryphaena hippurus. Because it also did so well on tunas, this use has become quite widespread. Today, fishermen claim that live bigeye scad results in better than twice the catch rate obtainable with frozen bait.

Recently, however, bigeye scad has become a very expensive market fish. In Oita Prefecture, for example, where they have been rearing this fish for use as longline bait, the trend has been towards marketing it as food fish rather than as longline bait. If the price for this fish stays up, it will undoubtedly be used less as longline bait in the future. Coastal longline fishermen may experiment with other species.

I. ANTARCTIC KRILL

According to the Japan Marine Fisheries Resource Research Center (JAMARC), many nations indicated interest in the Antarctic krill resource during the October 1974 FAO meeting in Rome. As a result, FAO will begin to include krill harvest in its annual world fishery statistics, and information on the krill resources, survey results, etc. will be disseminated through FAO. The krill is an important unutilized resource that has the potential of solving some of the world's food problems.

According to JAMARC, there are about 80 species included among the "krill," 30 of which are euphausiids. A good example is the Euphausia superba. This species grows about 3 cm per year and reaches a size of 5-6 cm in 2 years. It spawns from November through March, with each female spawning from 2,000 to 30,000 eggs depending upon its size. Life-span is believed to be about 2 years.

The krill is the principal food of the baleen whales in the Antarctic. The resource has been variously estimated from 100 million to 600 million tons; some estimates have been much larger. The maximum sustainable yield has been estimated at 50 million to 100 million tons. No matter, it is true that the krill resource is very large.

These tiny animals occur in swarms or patches which have been estimated to range from a few meters to as much as 10 km across. The swarms apparently appear at the surface during the day and sink at night. They are abundantly distributed between lat. 60° and 75°S, particularly in such locations as the Weddell Sea and the Scotia Sea, in waters with temperature ranging between 0.3° and 2.0°C.

The Japanese and the Russians are probably equally advanced in krill harvesting techniques today. Both report catching 1 or 2 tons per trawl tow, and catching as much as 10 tons per tow in exceptional cases. Both are using the midwater trawl, making tows between the surface and about 70 m in depth. The Russians are scouting for krill patches visually, while the Japanese report scouting visually as well as with fish finders. The Soviets are said to have about three stern trawlers of the 3,500-ton class harvesting krill.

JAMARC has for the last 3 or 4 years sent a chartered stern trawler to the Antarctic. The report on the present charter cruise is as follows:

Vessel: No. 11 Taishin Maru, 1,500-ton stern trawler
 Survey area: Antarctic Ocean (Weddell Sea)
 Survey period: October 30, 1974-March 31, 1975

On November 1, 1974 the vessel departed Cadiz, Spain and entered Cape Town on November 26 to make final preparations. Departed Cape Town on November 29 and arrived on the fishing grounds on December 4. Started searching for krill patches using fish finder. Fishing began on December 6 at lat. 63°-65°S, long. 55°-66°E (northeast of Cape Ann, Enderby Land). Fished until the end of December, and in 22 days trawled 166 times, resulting in a catch of 262 tons of krill. The largest catch per day during the period amounted to 25.7 tons; the best catch in a single tow was 7.1 tons.

JAMARC reported that as of February 15, 1975 the vessel had taken 961 tons of krill. As far as catching technique is concerned, JAMARC officials are quite satisfied with progress made over the last 3 years of exploratory work. Although several types of nets had been prepared, only the midwater trawl seemed to work efficiently. It also had the advantage of being able to fish in winds of up to force 6 or 7. The midwater trawl had a mouth opening of 10 x 10 m; total length of 48.7 m. Trawling was done using special otter boards made of aluminum alloy of neutral buoyancy, 3.6 x 2.5 m in size. The method of towing was the same as in regular trawling but the towing depth was adjusted by changing warp length or ship's speed. The average towing time was about 45 minutes at a ship's speed of 1.7 knots. The catch per tow averaged around 1 ton. Both the Russians and the Japanese have found the best fishing to occur in January.

The Nippon Suisan Company, a large Japanese fishing firm, recently sent its 3,600-ton stern trawler, Aso Maru, to the Antarctic Ocean to fish commercially. The reported catch was 1,600 tons of krill. The company is now working on product development.

The problem remaining at the moment is product processing and utilization. It has already been learned that krill frozen

immediately after capture tends to lose much of its nutritive body fluids when thawed. A better method is to boil the krill before freezing. As for utilization, the Russians have developed a product called "krill paste" which is being marketed in frozen blocks. This paste reportedly has a very fine flavor and the odor of shrimp, and is a product very well accepted by consumers for flavoring salads or mixing with butter or cheese. The Russians are also using the krill to make meal as well as a product called "pressed cake."

The Japanese have sent samples of krill to various laboratories to work on product development. As of now, some use has been made of krill as soup stock, or as tsukudani, where krill is cooked in soy sauce. Work is proceeding on using krill to manufacture "FPC," or protein concentrates. JAMARC is interested in developing products that would have universal appeal rather than something that would be suitable to the Japanese palate alone.

Undoubtedly, krill will figure more importantly in the future as the problem of feeding the growing world population becomes more critical. Several other nations have indicated interest in the krill. West Germany and Norway are now planning to dispatch survey ships to the Antarctic during the next krill season.

J. UNUSUAL ABUNDANCE OF EEL (UNAGI) ELVERS

Although the most recent statistics are unavailable, I have heard that in 1970, the annual consumption of unagi in Japan amounted to around 30,000 tons. Of this amount, Japan was able to produce 20,000 tons, and the remainder had to be imported. Furthermore, it was reported that of the 20,000 tons produced domestically, 17,000 tons comprised "cultured" eels, and 3,000 tons were fish taken in the wild. The remainder came from Korea and Taiwan. Eels are one of the favorite food fishes in Japan, and are served at specialty restaurants. Today, the Japanese are often heard to say that unagi dishes are now so expensive that they can rarely afford to enjoy them. The reasons for the high prices are the scarcity of "wild" eels, the high cost of "culturing" (in effect, it is "rearing" rather than "culturing"), and the need to import elvers for rearing.

In recent years Japan has been depending more and more on the so-called cultured eels where elvers are reared to marketable size. Because of the shortage of elvers in Japan, they had to be imported from such countries as France, Spain, South Korea, and Indonesia at very high prices. During my visit to an "eel culturing cooperative" in Hamamatsu, Shizuoka Prefecture, I was told that prices of elvers reached a record high of 400,000 to 500,000 yen per kilogram (\$627 to \$784 per pound) a few years ago because of general scarcity. In February 1975, during my visit, prices had fallen to 15,000 yen

per kilogram (\$24 per pound) and even lower in places. The reason for this great decrease in elver prices was the unusually high abundance of elvers in Japanese coastal waters this year.

For the first time in 10 years, elvers have appeared in great quantities off the Pacific coast extending from around Shikoku Island to the vicinity of Shizuoka in Honshu. In Shizuoka, the elvers first made their appearance around December 1974, about a month ahead of the usual elver season, which extends into March. At Lake Hamano, about 50 km west of Shizuoka City, fishermen are busily harvesting elvers by using set nets (teichaku ami) placed just inside of the lake entrance. According to the officials of the cooperative, fishing is done at night, as the incoming currents sweep the elvers into the large net. The cod end is lifted at hourly intervals to remove elvers caught in the net. No lights are used.

After some initial mortality the elvers apparently do quite well, with about an 80% survival. They are taken to the rearing areas where they are held in cages, 2 kg of elvers to a cage, suspended in fresh water. These transparent elvers, 5-7 cm in length, are said to be about a year old when captured. They change color in a few weeks, becoming quite dark and nearly doubling in size. As the elvers grow they are transferred to larger rearing ponds and fed regularly on specially prepared powdered food. Adults are fed mackerel and other fish.

During winter, the rearing ponds are heated to about 25°C to induce feeding and rapid growth. The water is aerated by stirring with a paddle-wheel contraption. The elvers increase in length to 20-30 cm in 2 years. (According to one official, this amount of growth requires 10 years in nature.) The eels are marketed soon thereafter. When asked about spawning grounds, the official replied that these eels are believed to be spawning in the vicinity of Taiwan, but that there may be some spawning also off southern Japan, with elvers being swept north along the Kuroshio. The low prices for elvers may not affect the retail prices of eels too greatly since rearing costs continue to be very high, particularly the cost of fuel oil necessary to heat the water in the rearing ponds during winter. (Many of the details given in this section were recorded during my interview with the cooperative official, but they are unverified and may contain errors in detail.)

K. JAPANESE COASTAL FISHERMEN ENCOUNTER PROBLEMS WITH SOVIET FISHERMEN

On February 17 I saw a television newscast showing Japanese coastal fishermen demonstrating in large numbers, asking the Government to intervene in their behalf in regard to the problems they have been encountering with Soviet fishermen. The news report indicated that Soviet trawlers off Kinkazan (northeastern Japan) were damaging nets used by Japanese coastal fishermen, thereby causing painful financial losses. Later, I learned that 30-40 Soviet trawlers were fishing around huge mother ships of 20,000-30,000 tons just over 3 miles from the Japanese coast. By mid-February, the fleet had moved southward to off Choshi (approximately the latitude of Tokyo), where they were harvesting mackerel by stern trawling. Japanese Coast Guard helicopter crews reported sighting several fleets of trawlers just outside of the 3-mile zone. They reported that mackerel fishing was being done by stern trawling, and that the catches were being processed on board the mother ships (canning factories). Heads, tails, and entrails of mackerel were being tossed overboard.

The Japanese fishermen reported that their small vessels (30 tons in size) are absolutely no match for the Soviet trawlers, which are about 400 tons in size. They have already sustained heavy damages to fishing gear. In December, Japanese fishermen reported suffering \$121,000 in damages to nets off Iwate Prefecture. This year, they reported damages totaling \$241,000 in 12 separate incidents. Off Choshi, the damages in two reported incidents totaled \$55,000. There were other reported incidents, bringing total losses to many thousands of dollars.

An even worse fear looms ahead. Mackerel spawning off Shizuoka is coming up soon and the Japanese feel certain that the Soviet fleet will move southwest to harvest the spawning fish. If they do, the coastal fishermen are afraid that the mackerel resource will be decimated. They are appealing to the Government to come to their assistance, and if possible, declare a 12-mile fishery zone in Japan.

So far, the Japanese fishermen have complained to the Soviet Embassy in Tokyo with no results. But news reports indicate that the Japanese Foreign Ministry is meeting with the Russians to work up some amicable solution to this problem.

L. MISCELLANEOUS

1. Sardines

Catches of sardines began to increase in the spring of 1973, and the year's catch amounted to 200,000 metric tons. The catch was reported to be even better in 1974, when an estimated 500,000 metric tons were anticipated. In February 1975, sardines were reportedly being taken in such large quantities that they were being given away at some of the northern ports.

2. Building Boom Continues for Large Skipjack Tuna Vessels

In February, more than 10 large (499-ton) skipjack tuna fishing vessels were being constructed, mostly under order from Mie Prefecture. This trend towards larger vessels is due to the greater distance to fishing grounds and the need for vessels of larger carrying capacity. A 434-ton vessel reportedly can carry about 300 tons of fish; a 499-ton vessel should be able to carry 400 tons. Large vessels such as these started fishing around September 1974, but their efficiency is not yet clearly determined. The opinion being expressed now is that such large vessels will do very well during good seasons such as 1973 but poorly during such years as 1974, when fishing was relatively poor and bait mortality high.

3. Roback Automatic Fishing Machines

According to officials of Iwatani & Co., sales agent for the Roback automatic fishing machines, there are now 25 Roback fishing machines installed on Australian vessels, 4 in Hawaii, 15 on the west coast, and about 600 machines on Japanese vessels. The company has received inquiries from Spain and France. An order for machines has come from Canada. An albacore vessel being built in Seattle apparently will install 10 machines and thus greatly automate its fishing capabilities.

M. LIST OF PERSONS CONTACTED DURING TRIP

Far Seas Fisheries Research Laboratory, 1000 Orido, Shimizu

Dr. Akira Suda,	Chief, Research Planning and Liaison Office
Dr. Shoji Ueyanagi,	Chief, Division of Pelagic Resources
Mr. Koichi Hisada,	Division of Pelagic Resources
Mr. Misao Honma,	do.
Dr. Shoji Kikawa,	do.
Mr. Susumu Kume,	do.
Dr. Shou Morita,	do.
Mr. Yasuo Morita,	do.
Mr. Yasuo Nishikawa,	do.
Dr. Chiomi Shingu,	do.
Mr. Toshiro Shiohama,	do.
Dr. Ichiro Yamanaka,	Chief, Division of Oceanography
Dr. Mito,	do.
Mr. Hajime Yamanaka,	do.
Mr. Mori Yukinawa,	do.

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 Mr. Yoshinobu Konishi, Division of Resources Research
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 Dr. Rikiichi Ishida, Chief, Division of Resources
 Dr. Kohei Kasahara, Section Chief, Division of Resources
 Mr. Masahiro Asano, Division of Resources
 Mr. Tsutomu Tanaka, do.
 Mr. Masakazu Yao, do.
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PROJECT PROPOSAL--BACKGROUND DOCUMENTATION

FISH AGGREGATION STUDY

April 9, 1975

wmm

The initial phase of the fish aggregation study involving the examination of past studies and records of fish schools associated with drifting objects has resulted in sufficient information for us to press for the implementation of the project. The following highlights form the basis for our recommendation:

1. In recent years the Japanese have expanded their skipjack tuna fishing operations into new grounds, eastward nearly to Midway Island and southward past the equator. The southward expansion has substantially increased their total production of skipjack tuna. In the 1973 fishing season (July 1973-May 1974), for example, the southern water fishery contributed over 100,000 MT (metric tons) of skipjack tuna. All of this increase came through live-bait fishing, while purse seining contributed another 1,100 MT. The Japanese are aware that their southern water fishery has expanded to near its maximum eastward range due to limitations imposed by baitfish supply and survival, and have begun to experiment with purse-seining methods in recent years. Although the results were poor in the first 2 or 3 years, there were some improvements in the last year, 1974.

American seiners also have attempted to fish in equatorial waters of the central Pacific in the last few years, but have met with mixed results. Good catches were made in a few sets, but fishing in general throughout the several trips were disappointing.

2. Four things were cited for the overall poor showing by both Japanese and American seiners: (a) the generally low school contacts, (b) the wildness of the schools, (c) the deep thermocline, and (d) the clarity of the water. We believe that the use of floating objects, whether natural or artificial, could improve or counteract all four factors listed above.

a. Low school contacts.

A weakness about the surface fishery (both pole-and-line and purse seining) is its dependence upon fish schools or bird flock sightings. We know from past studies and observations by this Laboratory that (1) sightings of bird flocks and fish schools diminish with adverse sea and weather conditions, which affect visibility and reduce bird activity; and (2) both the number of birds, and consequently the number of bird flocks, encountered diminish as distance from land increases.

The consequence of this reliance upon sightings is evident in the configuration of the principal fishing areas for skipjack tuna; the bulk of the catches are made within 500 miles or so from land. Of significance, of course, is the similarity in

the maximum distance from land in both the American and Japanese fisheries, including the latter's southern water fishery. It is doubtful that such things as bait holding and survival capabilities and vessel range limitations has too much to do with the similarity in the 500-mile range. The Japanese southern water fishery has demonstrated that bait can be transported over long distances, from home waters to the Marshall Islands, a distance well beyond the 500-mile limit, and the American fleet of purse seiners consist of vessels capable of operating well beyond this limit.

The reduced bird flock sightings in oceanic areas and the range of the present fisheries leads one to conclude that the skipjack tuna is land associated. However, studies showing both adult and larval distribution to be continuous across the Pacific with comparable densities in open ocean as well as near land suggest that this is not completely so. Which leads to the observation that there could be more skipjack tuna in the open ocean than one would suspect, perhaps even as much as that found in the present fishery areas.

One way to improve school contacts in mid-oceanic areas is to set out numerous floating objects. Past studies have shown that skipjack tuna schools are attracted to floating objects and the Japanese have found that skipjack tuna can be caught around drifting logs in the absence of surface signs of schools. Utilizing this knowledge they have tried such objects as two 55-gal oil drums lashed together and a string of 2-m square rafts lashed 100 m apart. From the vicinity of the 55-gal drums they were successful in catching up to 20 MT of skipjack and small yellowfin tunas with the purse seine after about 6 days of drift. Reports by the Japanese pole-and-line vessels fishing around floating objects also indicate respectable catches of skipjack tuna. These varied from an average of 6.4 MT per fishing operation on new objects not long adrift to 9.0 MT on old, long-drifting objects.

Recent information from Japan (Otsu's February 1975 trip) on their purse-seining operations in Papua New Guinea waters in the past year include the following:

- (1) Although seining for skipjack tuna in equatorial waters was poor a few years ago, recently, the vessels have been experiencing 80% success (i.e., positive sets) with an average catch approaching 10 tons per day, roughly half the average catch rate of seiners in the eastern Pacific fishery.

- (2) Most catches were made around floating logs. Whenever logs were encountered, they were marked by radio buoys and sets were made only in late afternoon or early morning.

Based on the experience of the Japanese, a catch of 20 MT from the vicinity of two 55-gal drums and an average of 10 MT per set, mostly from around floating logs, it does not seem unreasonable to envision a catch rate equal to that made in the eastern Pacific seine fishery. All that would be required to accomplish this is to set out sufficient drift objects to permit two sets in early morning and two sets in late evening, with none of the objects being fished more than once every 5th or 6th day.

b. Wildness of schools.

Wild or fast-moving schools pose a greater hindrance to seining than to pole-and-line fishing. While these schools are on the move they are practically unfishable with the seine. However, those schools that have become attracted to floating objects and have slowed down in their movement may be fishable, as demonstrated by the success of the Japanese seiners. Consequently, fishing could be made possible even in areas containing fast-moving schools by setting adrift a number of floating objects, the number of desired contacts being determined by number of these objects.

c. Deep thermocline.

There is sufficient information in the literature to show that skipjack tuna abound in areas with deep as well as shallow thermocline. Any measure, aside from enlarging the net, that would minimize or counteract the effects of the deep thermocline could increase the chances of success by seining. The Japanese seine catches north of Papua New Guinea, where the thermocline is deep (80-100 m), proves this point. If the drift objects can attract fish schools vertically from subsurface, as inferred in the purse seine success by the Japanese, they would minimize the disadvantage of deep thermoclines.

d. Clarity of the water.

The complaint about clear water is that the fish are able to see the net and thus escape capture. Unlike the deep thermocline situation, where nets can be made to fish deeper, little can be done to change the clarity of the water. Drift objects

placed in such waters, however, can benefit by being more easily seen by fish schools from greater distances, both horizontally and vertically. Also once these schools have been attracted, the floating objects could hold the schools long enough for sets to be made on them.

3. The use of floating objects could also be an aid to pole-and-line fishing in mid-oceanic sites. School contact rates by bait boats also could be improved greatly, if instead of encountering drift logs only by chance, a large number of these were to be placed close enough to each other so that several of them could be visited by a single vessel during the course of a day's fishing. Publications by the Japanese on records of fishing around drift logs show that skipjack tuna and small yellowfin tuna could be caught by chumming near the logs even in the absence of surface signs of tuna schools. Other reports (Kimura, Iwashita, and Hattori, 1952) show that skipjack tuna schools picked up on the sonar can be brought to the surface from as deep as 140 m by chumming.
4. We envision a major expansion of skipjack tuna fishing into mid-oceanic areas in the future. In fact this may be the only way to go if the U.S. industry wishes to increase the skipjack tuna landings. Such a move, however, will naturally result in reduced school sightings, as set forth above. The fish aggregation project is aimed at correcting this by increasing school contact rates both for seining and baitfishing, and possibly to make skipjack tuna schools more susceptible to purse seining in waters now considered disadvantageous for this type of fishing.
5. Purely on academic merits the project could give us a better insight on the distribution and abundance of skipjack schools in mid-oceanic areas:
 - a. Based on currently available fish observation data, one would conclude that the skipjack tuna are associated with land masses. Yet the nearly continuous distribution of larvae in equatorial waters across the Pacific and a similar distribution of catches of adults by the longline suggest the opposite. How much of this apparent association with land is due directly to the fishery's dependence upon bird flock sightings, which are also land associated, needs to be determined.

Sufficient coverage of an area with adequate floating objects could give us an idea of the density of schools not now known from observations based only on bird flocks or surface school sightings. Additional data leading to a better estimation of school density in mid-oceanic waters could provide us with better estimates of the resource in the Pacific Ocean.

- b. Additionally, more observations of drift objects could lead to a better understanding of the mechanics involved in their attractiveness to schools. At the moment, the only plausible theory advanced by the few who have studied drift objects seems to be that the objects act as schooling companions. This needs to be investigated further.
- c. Physiological studies on the skipjack tuna done at the Honolulu Laboratory (mainly by Neill) indicate that those factors which tend to limit the distribution of these fish are (1) the lower lethal temperature (approximately 14° to 18°C), (2) the lower lethal dissolved oxygen concentration (2.8 to 3.5 ml/liter), and (3) an upper temperature bound which varies with size and metabolic rate of the fish, e.g., 30°C for fish weighing 1 kg and 20°C for a 12 kg fish. Because skipjack tuna can exceed their thermal limits for short periods of time, they could forage in water which is too warm, provided that cool oxygenated water is available immediately below it, and vice versa.

Translating these limits to the ocean, Barkley has come up with a description of the hypothetical skipjack tuna habitat. The normal habitat of all but the smallest skipjack tuna is not the surface layer, but the upper thermocline, for most of the year throughout most of their range. He also hypothesizes that medium and large skipjack tuna should not be found in much of the eastern tropical Pacific, where all the water with sufficient oxygen is warmer than these fish can tolerate.

The aggregation studies should provide evidence to either confirm or disprove these hypotheses.

- d. The above items, particularly 5a-5c, are in line with NOAA's policy governing fisheries programs as set forth in Major Policy and Program Recommendations to the President (Budget request for 1976). That policy is to "provide basic scientific knowledge on abundance, distribution and condition of our fisheries stocks" so that "proper utilization and conservation of our fisheries resources" can be achieved. The aggregation studies are also in line with NOAA's support of programs aimed at "improving the techniques of living marine resource exploitation" to the extent that such programs contribute to better utilization and conservation, and would not be readily undertaken by industry.
6. Finally, from the budgetary standpoint, the cost of the project, exclusive of ship time, would be nominal. The plan calls for testing four types of objects, each designed by incorporating the best features of drift objects from past studies. The most effective

one or two of these will be selected for use in mid-oceanic areas. The cost of the four types of objects to be tested would be in the neighborhood of \$900. The nominal cost involved would definitely warrant the initiation of the project.



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April 29, 1975

Minutes of Baitfish Committee Meeting
Held on April 24, 1975, 10 a.m.

Present:

Wayne Baldwin, Hawaii Institute of Marine Biology, UH
John Ball, Sea Grant Programs, UH
Andrew Gerakas, Hawaii State Dept. of Planning & Economic Development
Rudy Kunihiha, Bumble Bee Seafoods, Castle and Cooke
Jay Puffinburger, Hawaiian Tuna Packers
Michio Takata, Hawaii State Fish and Game Division
Robert Iversen, Regional Representative, NMFS, Honolulu, HI
Harvey Moore, NMFS Regional Office, Seattle, WA
Brian Rothschild, Director, Southwest Fisheries Center, NMFS, La Jolla, CA
Donald Aasted, Honolulu Laboratory, NMFS
Roger Green, Honolulu Laboratory, NMFS
Tamio Otsu, Honolulu Laboratory, NMFS
Richard Shomura, Honolulu Laboratory, NMFS
Jerry Wetherall, Honolulu Laboratory, NMFS

The meeting was called to order by Richard Shomura.

A film of bait aging and transporting activities at California, Hawaii, and en route on the roll on/off freighter was shown by Mr. Aasted.

Mr. Shomura reviewed details of the three alternative baitfish activities presented at the Baitfish Committee meeting of 8 April 1975:

1) Continue work on the transport of northern anchovy by the roll on/off method. Before any further California-Hawaii shipments are made, extensive experiments should be conducted to define baitfish quality and determine the effects on survival of density, oxygen levels, and handling methods. For a number of reasons Honolulu Laboratory personnel proposed a shift of the base of operation from Long Beach to Tiburon, California. A prime consideration was that Matson Navigation Co. had recently initiated a roll on/off service from Oakland to Honolulu; thus, if the experiments prove that the system is economically feasible, a full scale system of moving anchovy from California to Honolulu could originate from the San Francisco Bay area. Another factor favoring the Bay area was that small anchovy of the size considered most suitable for the Hawaiian aku fishery occur in abundance during the summer months in the Bay area, thus coinciding in time with the peak aku fishing season in Hawaii. Other advantages include the ready accessibility of a suitable docksite area at the Southwest Fisheries Center facility (Tiburon Laboratory) located in Tiburon, California, and the generally better water quality found in the San Francisco Bay area as compared to the Long Beach-Los Angeles Harbor area.

The experiments would answer questions now considered vital to further work involving the tank-trailer transporting method and would also supply information useful to other bait handling and transporting methods. The experiments would be followed by a trial shipment of bait from Oakland. Total costs, exclusive of NMFS labor and facilities, were roughly estimated at \$15,000-\$20,000.

2) Transport 1,000-3,000 scoops of anchovy by bait boat for tests of fishing effectiveness. The questions on the effectiveness of northern anchovy, relative to nehu, in taking aku is crucial to the feasibility of all bait transporting schemes under consideration. Under the present state of the art of bait transporting via tanker-trailer, the amount of anchovy delivered would be insufficient for any conclusive field tests on effectiveness. The technological feasibility of delivering sufficiently large samples by west coast bait boats has already been established. In addition to supplying bait for fishing tests, the venture would supply more data on operating costs and survival rates that would be useful in evaluating the economic feasibility of using this system as a bait transporting system in its own right. Cost of the method was estimated to be in the neighborhood of \$20,000-\$25,000.

3) Supply threadfin shad from Wahiawa Reservoir during the 1975 aku season for fishing tests. Should bait transporting schemes prove infeasible, work should be underway to augment the local supply of bait in other ways. One of the more likely alternatives is the use of threadfin shad. Previous tests with threadfin shad have been limited and the results inconclusive. For a proper evaluation of fishing power using shad, it will be necessary to supply enough threadfin shad during the entire fishing season. Cost of the operation is estimated to be \$38,000. Part of the cost can be assumed by the Honolulu Laboratory should the project involve the Laboratory.

Mr. Kinney suggested that the work on the anchovy should include a fisherman experienced in the use and handling of northern anchovies in order to provide expertise in the evaluation of bait quality and to assist in developing an optional system.

Mr. Baldwin suggested a fourth alternative of conducting fishing tests using tabai (mosquitofish). The experimental culture now underway in Samoa could supply 200 buckets by the 1976 season.

The committee agreed that highest priority in future work should be given to the first two alternatives of roll on/off experiments at Tiburon and a single shipment of bait via a west coast bait boat. It was also agreed that work should begin on the shad experiments, if funding is available.

Mr. Gerakas suggested that funding for the three projects might be available from PTDF and requested that a proposal covering all of them be submitted next week for PTDF consideration. A detailed budget breakout for each option was also requested.

Table 1.--Distribution of tows by quarters.--Continued.

Countercurrent (Area 2 + 3 + 4 = 5° to 10°N; 110° to 170°W)

200-m Oblique	Year	Quarters with plankton tows				No. tows
		I	II	III	IV	
	1950	3			10	13
	1951	16	4	9		29
	1952	5	18		6	29
	1953	20				20
	1954	1				1
	1955			15	9	24
	1956	5		1	10	16
	1957				3	3
	1958	1	5		3	9
	1959					--
	1960					--
	1961				2	2
		51	27	25	43	146

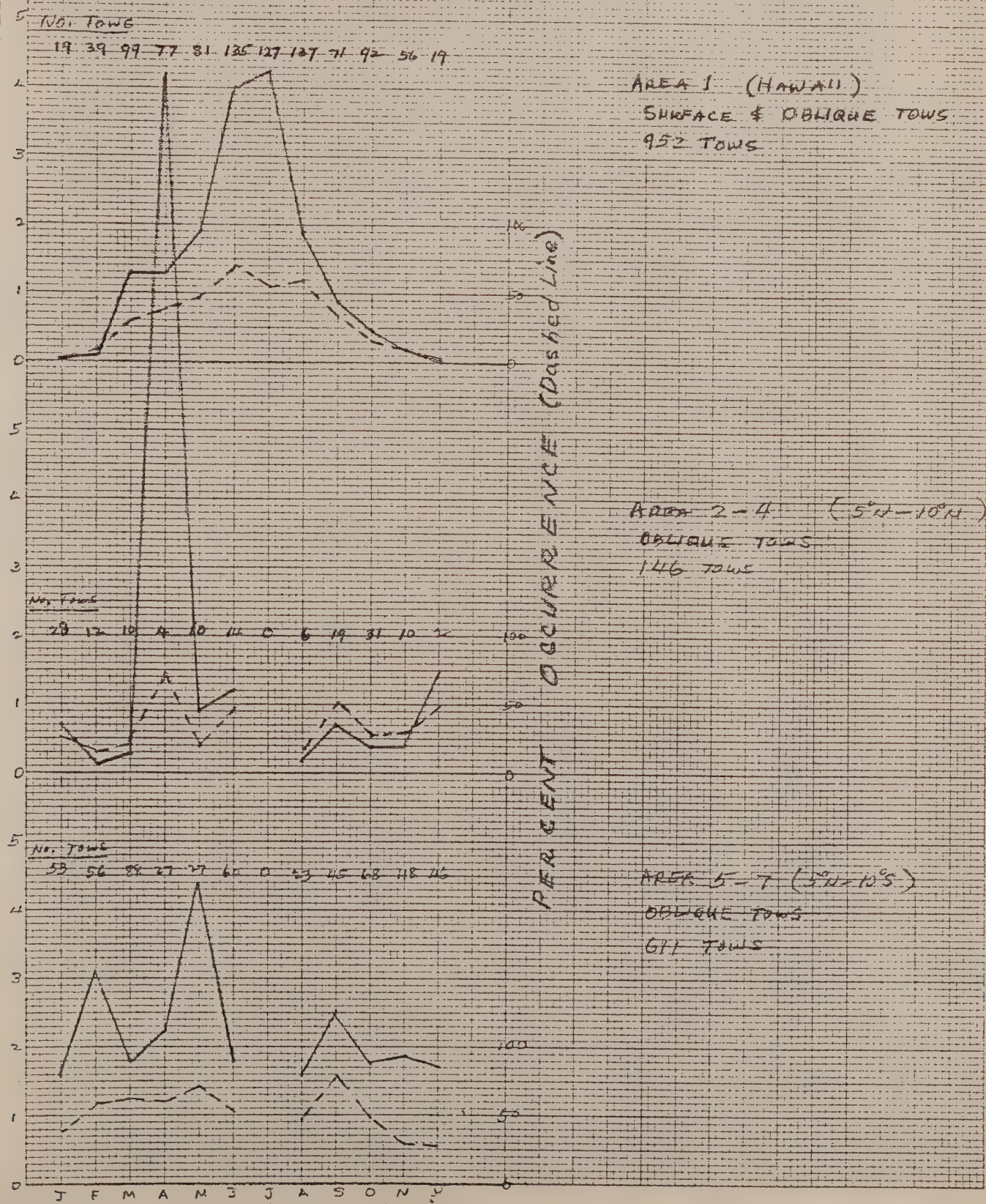
South Equatorial (Area 5 + 6 + 7 = 5°N to 10°S; 110° to 170°W)

200-m Oblique	1950	5			3	8
	1951	44	12	28		84
	1952	22	42	14	45	123
	1953					--
	1954	9	10			19
	1955				87	87
	1956	24		26		50
	1957	14			78	92
	1958	79	50		8	137
	1959					--
	1960					--
	1961				11	11
		197	114	68	232	611

1. — PLANKTON SAMPLES COLLECTED BY THE HONOLULU LABORATORY 1950-1969



Fig. 2 - LARVAL CATCH & OCCURRENCE BY MONTH
(ALL YEARS COMBINED)



OVERLAY FOR FIG. 3

ANNUAL LANDINGS OF SKIPJACK IN HAWAII

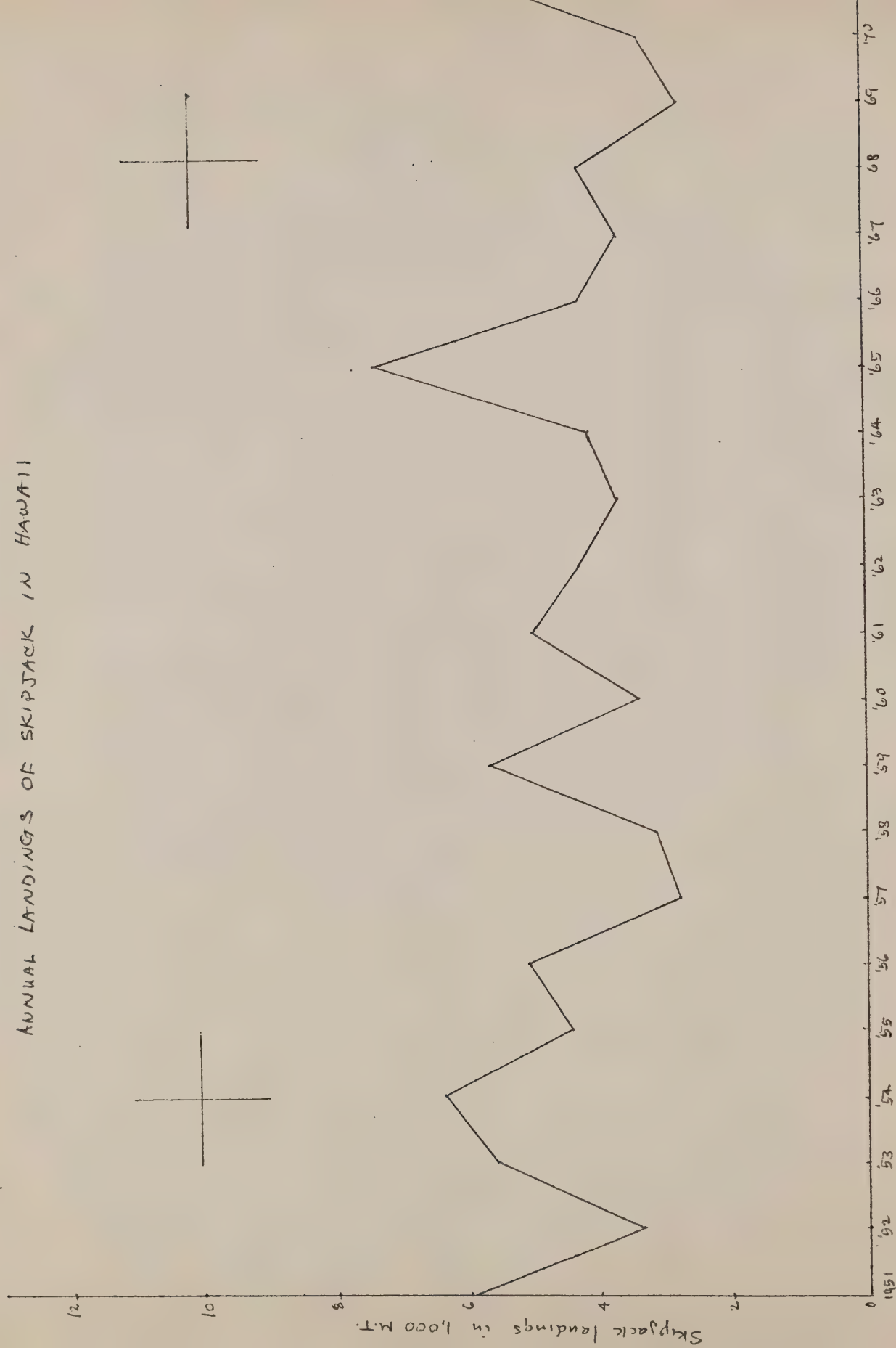
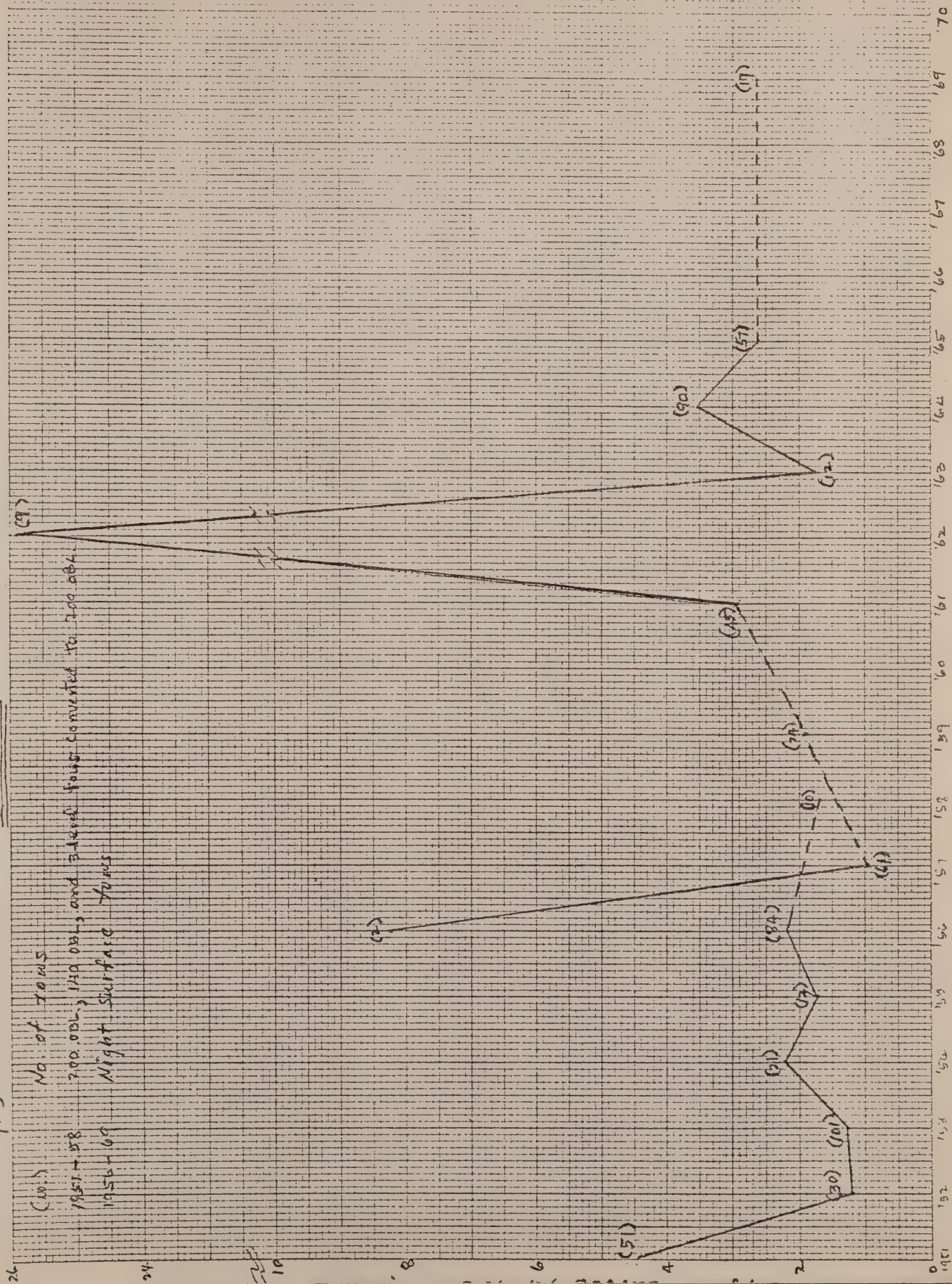


Fig. 3 - LARVAL SKIPJACK PER TON IN HAWAIIAN WATERS



OVERLAY FOR FIG. 4.

LANDINGS AND BAITBOAT CATCH-PER-DAY'S FISHING IN THE EASTERN PACIFIC

— TOTAL LANDINGS

— CPD'S FISHING STANDARDIZED TO CLASS 4 BAITBOAT

Landings in 1,000 metric tons
Catch per day's fishing

120
100
80
60
40
20

5
4
3
2
1

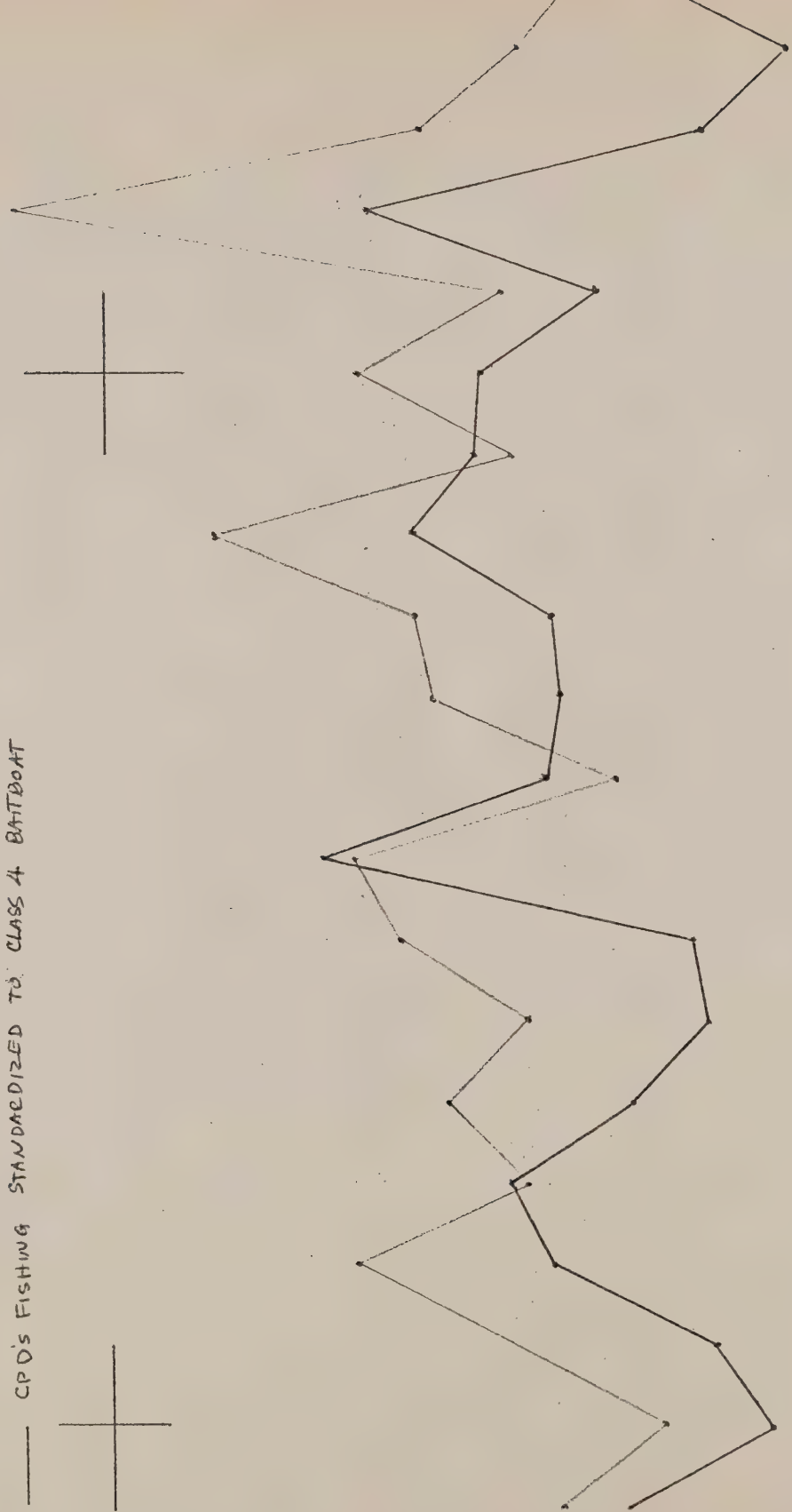
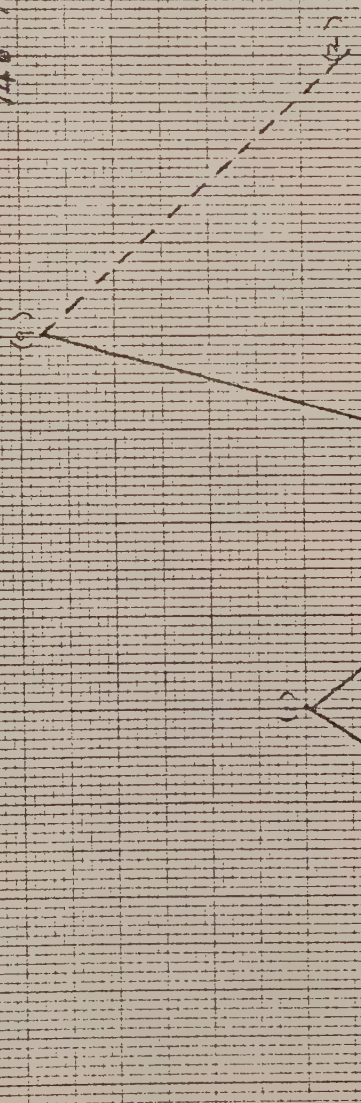
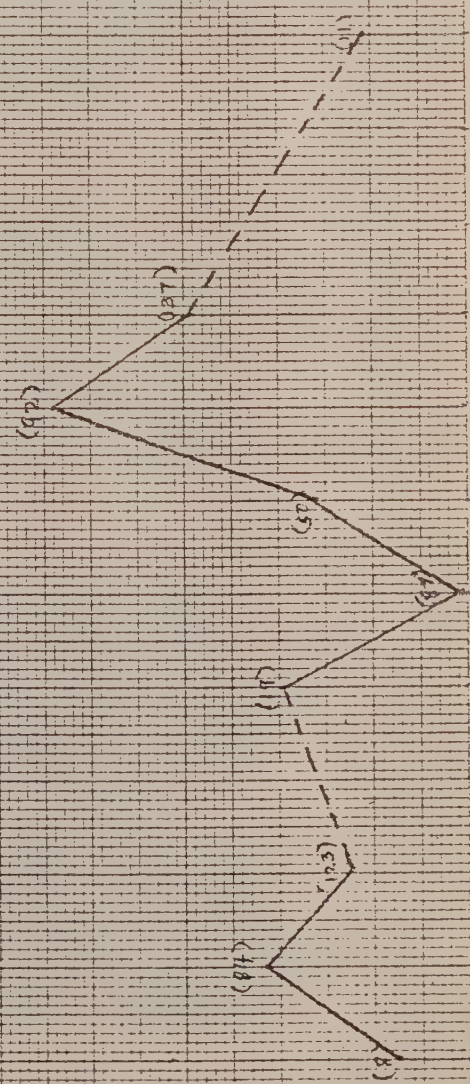


Fig. 4 — LARVAL SKIPPERS CAUGHT IN EQUATORIAL WATERS (OBLIQUE TOWS)

AREA 2+3+4 (5°N-10°N, 110°W-170°W)
(No.) Number of Tows
146 TOWS



AREA 5+6+7 (5°N-10°S, 110°W-170°W)
(No.) Number of Tows
611 TOWS





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A LOOK INTO THE RELATIONSHIP OF LARVAL SKIPJACK TUNA TO COMMERCIAL LANDINGS IN HAWAII AND EASTERN PACIFIC

Walter M. Matsumoto

Sampling for tuna larvae has been done over many years by the Honolulu Laboratory and has resulted in the accumulation of a large number of plankton samples. However, due to spotty coverage of both time and space and the employment of various types of towing methods, the usefulness of the data for large area-long term considerations is limited. We can thus look at the relationship of skipjack tuna larvae to commercial landings only on a very rough basis.

Definition of Areas

Figure 1 shows the number of tows made in each 5° square sampled by our vessels and the areas selected for this analysis. The areal separation was based roughly on the major ocean currents: Hawaii, in the North Equatorial Current, from 10°N to 30°N; Equatorial Counter-current (ECC), from 5°N to 10°N; and South Equatorial Current (SEC), from 5°N to 10°S. Each of the areas within the ECC and SEC was looked at separately, but the distribution of tows in each area was too spotty for analysis. Consequently, the three areas in the ECC were combined, as well as those in the SEC. Even so, the data still showed gaps in the yearly coverage (Table 1).

Hawaii (Area 1)

Because of poor sampling in the first and fourth quarters (Table 1) and the fact that nearly all of the larval catches occurred in the second and third quarters (Figure 2), the larval catches were plotted by year instead of by quarters. It is of course assumed that since spawning occurs nearly equally in the second and third quarters, the catch rate in either quarter or in both quarters combined would be a representative measure of the yearly abundance of larvae.

Figure 3 shows the skipjack tuna larvae taken per tow, with catch rates plotted separately for the surface and oblique tows. The overlay for the figure shows the annual landings of skipjack tuna by the local aku fleet. The catches in the overlay are given in annual landings rather than in (Uchida's) catch per standard effective trip (CPSET), since the two do not differ by much and the CPSET values were not available beyond 1965.

Despite doubts about the data, a simple test (Spearman rank correlation coefficient: r_s) was made to see if any possible relationship existed between larval and adult catches. Summary below:

Surface tows

	<u>r_s</u>	<u>t</u>	<u>df</u>	<u>P(2-tail)</u>
Same year	0.217	0.588	7	>0.50
1 year lag*	0.158	0.423	7	>0.50
2-year lag	Negative			
3-year lag	0.533	1.667	7	>0.10

Oblique tows

Same year	0.679	2.068	5	<0.10
1 year lag	Negative			
2-year lag	Negative			
3-year lag	0.214	0.490	5	>0.50

*Fish catch 1 year after larval catch.

The larval catch curve for the oblique tows appears to follow that of the annual landings for the same year. Although the test showed no significant correlation, perhaps more data points could have provided positive results. It seems logical to expect that a large spawning would reflect the presence of a large spawning population, which in turn would result in large catches of adults. Other comparisons with a 1 year, 2-year or 3-year lag in the landings curve were far from being significant.

The closest to being significant among the surface tows was the 3-year lag comparison. The failure to attain significance could have been due to lack of data in 1958, 1960, and 1966-68. Other causes, however, cannot be ruled out. For example, the local fishery is extremely confined in range. Consequently, its annual catches may not truly reflect the abundance of fish in the area. Seckel has shown that good catches by the fishery occur when the transitional water in the California Current Extension passes through the island chain and low catches when this water is either to the north or south of the islands. If the skipjack tuna are truly associated with this type of water and the center of abundance shifts in unison with it, then those years of poor catches could be the result of the fleet's inability to reach the concentrations of fish rather than an indication of a drop in the abundance of the fish. If this situation holds true, then there is no reason to expect correspondence between

larval catches and commercial landings in these waters. This would be especially true when the transition water moves to the north of the islands, for fish could spawn in local waters during their passage northward and be out of range of the fleet within a day or two.

Closer correlation could be obtained if sampling for larvae had been confined to within the limits of the fishery. Although the number of tows are large within the 5° squares adjacent to the islands, most of these tows were from sites beyond the range of the fleet.

Equatorial Countercurrent (Areas 2-4) and South Equatorial Current (Areas 5-7)

Figure 2 (lower two panels) shows the occurrence and catch of skipjack tuna larvae by month. With a few exceptions, larvae have been taken relatively evenly throughout the year. Consequently the catch rates of any or all quarters were assumed to be a representative measure of the yearly abundance of larvae.

Figure 4 gives the catch rates of skipjack tuna larvae in the ECC and SEC areas. The catches are all from oblique tows, since surface tows were not made there over any extended period. The overlay for Figure 4 gives the total annual landings and catch per day's fishing standardized to Class 4 bait boat. The standardized CPDF was used because data points could be found or estimated to the year 1951. As in the Hawaii data the Spearman rank correlation test was used to determine the larval-adult relationship. The summary of the test is as follows:

Equatorial Countercurrent

	<u>r_s</u>	<u>t</u>	<u>df</u>	<u>P(2-tail)</u>
Same year	0.067	0.178	7	>0.50
1-year lag	0.636	2.331*	8	<0.05
2-year lag	0.539	1.811	8	>0.20
3-year lag	Negative			

South Equatorial Current

Same year	Negative	1.459		
1 year lag	Negative		7	>0.37
2-year lag	0.483	1.459	7	>0.17
3-year lag	0.167	0.449	7	>0.50

Taking these results for what they are worth, it seems that there is a significant correlation between larval catch in the Countercurrent area and fishery landings 1 year later. At least the large proportion of small fish taken in the eastern Pacific fishery, if these are 1 year olds, bear this out. On the basis of an equally large proportion of 50-60 cm fish in the eastern Pacific, there should also be a significant correlation between larval catch and adult catch 2 years later. This could show up with better sampling.

There also is a likelihood that the 2-year lag correlation in the SEC area could be significant with better sampling data. If so, the question is, could some of these fish also swing north, thence eastward, and into the eastern Pacific fishery?

Countercurrent vs. Hawaii

Several authors have suggested that some portion of the skipjack tuna landed by the Hawaiian fishery come from the ECC area. Such a movement is not discernible from a comparison of larval catches in the ECC and commercial landings in Hawaii (below):

	<u>r_s</u>	<u>t</u>	<u>df</u>	<u>P(2-tail)</u>
Same year	Negative			
1 year lag	0.224	0.649	8	>0.50
2-year lag	0.212	0.614	8	>0.50
3-year lag	Negative			

The lack of correlation again could be due to insufficient sampling of larvae or to the unreliability of the Hawaiian landings, per above discussion.

Closing Remarks

The lack of significant correlation between larval catches and skipjack tuna landings in Hawaiian waters could be due to inadequate sampling for larvae, to the restricted range of the fishing fleet, or to both. Meaningful data to assess adult abundance in these waters and to determine better larval-adult catch relationships may not be possible until the Hawaiian fleet increases its capabilities to fish over a wider range.

Whether the significant correlation found between larval catches in the Countercurrent area and adult catches in the eastern Pacific fishery is real or fortuitous, remains to be seen. My reservation is due to doubts about (1) the adequacy of the larval catch data in the area east of 140°W, and (2) the failure of the 2-year lag comparison to show significant correlation, contrary to what one would expect from looking at the size composition of the catches in the eastern Pacific fishery.

Table 1.--Distribution of tows by quarters

Hawaii (Area 1 = 10° to 30°N; 145° to 170°W)

Oblique	Year	Quarters with plankton tows				No. tows
		I	II	III	IV	
	1951		39	12	74	125
	1952			30		30
	1953	60	29	72	6	167
	1954		21			21
	1955			12		12
	1956		40	44		84
	1957				19	19
	1958		8	2		10
		60	137	172	99	468
Square	1956			2		2
	1957		17	44	4	65
	1958					--
	1959			24		24
	1960					--
	1961		6	39		45
	1962			9		9
	1963			12	6	18
	1964	39	57	33	58	187
	1965	58	57			115
	1966					--
	1967					--
	1968					--
	1969		19			19
		97	156	163	68	484

BAITFISH DEVELOPMENTAL ACTIVITIES IN HAWAII
FOR 1975--A PROPOSAL

An expansion of the pole-and-line fishery for skipjack tuna (Katsuwonus pelamis) in Hawaii depends on a total replacement or the supplementing of the present supply of locally available baitfishes. The present supply of nehu (Stolephorus purpureus), the principal baitfish species available in Hawaii, is limited; based on present knowledge a substantial increase in catch on a sustaining basis cannot be expected from this resource. Details of the baitfish problem in Hawaii have been documented elsewhere.

In late 1970 an ad hoc baitfish committee was organized to review and evaluate on-going research on the baitfish problem. The committee is composed of members of the fishing industry (producers and processors in Hawaii), State of Hawaii Fish and Game Division, State of Hawaii Marine Affairs Coordinator, Pacific Island Development Commission/Pacific Tuna Development Foundation, Hawaii Institute of Marine Biology (University of Hawaii), the University of Hawaii Sea Grant Programs and the National Marine Fisheries Service. The committee recently met on April 8 and again on April 24, 1975, to review the status of the baitfish transport project presently conducted by the NMFS Honolulu Laboratory and to discuss future work. At the April 24, 1975 meeting, Mr. Andrew Gerakas as Chairman/President of the PTDF indicated that the Foundation would entertain proposals on baitfish work in Hawaii for financial support.

The following provides details of a proposal to PTDF for support of baitfish work in Hawaii:

SUMMARY

Three recommendations for further baitfish development work emerged from discussions of the ad hoc baitfish committee meetings of April 8 and April 24, 1975. The three projects recommended are:

1. Continue work on transporting northern anchovy (Engraulis mordax) via the roll on/off method. Factorial experiments with northern anchovy in San Francisco Bay need to be initiated in order to assess effects of bait quality, oxygen levels, salinity, and handling methods on survival rates. This is to be followed by a trial roll on/off shipment from Oakland, California.
2. Transport, via a west coast commercial fishing boat, one large shipment (1,500-3,000 scoops) of northern anchovy for use in fishing tests in Hawaii.
3. Provide threadfin shad (Dorosoma petenense) from Wahiawa Reservoir for fishing tests during the 1975 skipjack tuna season.

The committee's recommendation was unanimous that work be started on all three projects as quickly as possible. The majority of the members felt that should priorities be assigned, the first two projects should not be separated and should receive first priority.

Details of the projects follow:

ROLL ON/OFF EXPERIMENTS

For the past year, the National Marine Fisheries Service (NMFS) has been studying the feasibility of transporting anchovy from California via a 5,000-gallon tanker-trailer shipped aboard roll on/off freighters operating out of Long Beach. In six trial shipments, much has been learned of the technology and economics of such an operation. The basic transport unit, the tanker-trailer, has evolved to a highly advanced mobile, life-support system. Dockside experiments with it indicate that it is capable of delivering payloads of up to 1,100 pounds of live bait at reasonable cost. So far, however, the system has been able to deliver payloads of only about half this amount.

A number of unresearched problems appear to contribute to the system's failure to produce the expected results. What is the effect on shipment mortality of interacting factors such as initial bait viability, oxygen levels, density of bait, salinity, handling methods and water quality in holding tanks? Factorial experiments are planned to answer these questions, using as many small tanks (1,000 or more gallons each) as treatments and running successive lots of bait in 4-day experiments, ranking initial viability by both behavioral observations and sample blood cell volumes. The results of these experiments will be used in determining when and under what conditions to ship live bait by this or other methods.

Problems of high mortality in holding bait both in aging tanks and in the tanker-trailer have continually hampered the NMFS operation in the Long Beach-Los Angeles harbor area. Low bait quality (viability) and water quality chronic to the area appear to be prime suspects according to fishery biologists, bait dealers, and live-bait fishermen acquainted with this and other areas of the California coast. This site was chosen because the only two freighters suitable for this type of operation were scheduled between Long Beach and Honolulu. This situation has now changed. One of these freighters, Matson's Lurline, has moved its base to Oakland to operate full time between there and Honolulu. Because of this freight schedule change, the generally superior bait and water quality in San Francisco Bay, and access to research facilities, the experiments will be conducted at NMFS Tiburon Laboratory on San Francisco Bay. The experiments, lasting approximately 3 months, will be followed by a trial shipment of bait out of Oakland.

BUDGET FOR ROLL ON/OFF

	<u>NMFS</u>	<u>Other sources</u>
<u>Salaries</u>		
Consulting statistician	--	\$ 1,000
1 project leader, 10 weeks	\$ 4,947	---
1 technician, 2 weeks	925	--
1 technician, 4 weeks	1,956	--
Overtime and night differential	<u>931</u>	<u>--</u>
	8,759	1,000
<u>Travel</u>		
Per diem: 7 man-days @ \$30	--	210
GSA car rental (California)	250	--
Miscellaneous travel expenses	--	250
Air fare (2 round trips)	<u>--</u>	<u>600</u>
	250	1,060
<u>Utilities</u>		
Electricity	--	700
Water	--	<u>400</u>
		1,100
<u>Equipment</u>		
Tanks (10 @ \$300)	--	3,000
Pumps (5 @ \$1,084)	--	5,420
Plumbing (\$150 per tank)	--	1,500
Lumber, sand, concrete	--	900
Tank covers (10 @ \$50)	--	500
Oxygen meter	--	<u>865</u>
		12,185
<u>Operational expenses</u>		
Fish food	--	100
Live fish	--	10,000
Chemicals	--	1,200
Truck rental	--	<u>200</u>
		11,500

	<u>NMFS</u>	<u>Other sources</u>
<u>Trial shipment</u>		
Fare: tanker and attendant, trucking	\$ 1,675	--
<u>Miscellaneous and contingency fund</u>		\$ 3,000
	\$10,684	\$29,845

BAIT BOAT TRANSPORT

The question of the effectiveness of northern anchovy relative to nehu in catching skipjack tuna is crucial to the feasibility of all bait transporting schemes under consideration. For example, in the economic study of transporting bait via tanker-trailer on roll on/off freighter, the results are so sensitive to slight changes in the ratio of anchovy to nehu effectiveness as to overshadow all known variables in the outcome. Small payloads of anchovies transported to Hawaii in the past have been insufficient to give significant results concerning their relative fishing power.

The only feasible method presently available to transport sufficient quantities for a fishing test is the use of a west coast bait boat as a transporter. These vessels are already equipped to carry from 1,000 to 3,000 scoops of live bait on extended trips. With a delivery in this size range, fishing tests involving the entire Hawaiian skipjack tuna fleet could be conducted for up to 1-1/2 months. NMFS can supply labor for observations at sea and data processing. Limited fishholding facilities can be available if NMFS is not, at the same time, engaged in threadfin shad experiments. Otherwise, the transporting boat can be used to store the bait until used.

In addition to supplying bait for fishing tests, the venture would supply more data on operating costs and survival rates that would be useful in evaluating the economic feasibility of using this system as a bait transporting system in its own right.

BUDGET FOR BAIT BOAT TRANSPORT

	<u>NMFS</u>	<u>Other sources</u>
<u>Labor costs</u>		
Project leader, 1-1/2 months	\$ 2,629	--
3 technicians, 1-1/2 months	6,958	--
Overtime, night differential	<u>2,500</u>	--
	12,087	

	<u>NMFS</u>	<u>Other sources</u>
<u>Contract - bait boat</u>		
Estimate of negotiated contract based on costs of operating 100 ft. west coast tuna boat ¹	--	\$25,000
<u>Operational expenses</u>		
Bait boat for bait storage in Honolulu, if needed (30 days @ \$200)	--	6,000
<u>Miscellaneous and contingency fund</u>		<u>3,000</u>
	<u>\$12,087</u>	<u>\$34,000</u>

THREADFIN SHAD - FISHING EXPERIMENTS

Should bait transporting schemes prove infeasible, work should be underway to augment central Pacific supplies of bait in other ways. One of the more likely alternatives is the use of threadfin shad. These fish, an introduced euryhaline species, maintain a high standing population in Wahiawa Reservoir, Oahu, and the resource may be capable of producing a sustainable yield sufficient to supply much of the bait needs of the local skipjack tuna fleet. Threadfin shad possess most of the desirable attributes of ideal tuna baitfish and are amenable to culture in freshwater ponds. They can be acclimated to salt water before transfer to baitwells aboard fishing vessels.

Some short fishing trials have been conducted with threadfin shad in past years, enough to show that they can produce good results in catching skipjack tuna, but not sufficient to develop optimum fishing methods, nor to gain fisherman acceptance of the new bait. In switching to any alternate bait, new methods of use must be evolved to utilize their unique behavioral and appearance aspects. This cannot be done with small quantities of bait in short time periods.

The proposed work will extend through the peak fishing season, about 3 months, supplying threadfin shad from Wahiawa Reservoir and acclimating them at a rate of approximately 100 buckets per week. The fishing tests can involve the entire skipjack tuna bait boat fleet with bait apportioned on a random selection basis to those vessels that wish to participate. NMFS facilities to be used in the project include the

¹Green, Roger E., and Gordon C. Broadhead. 1965. Costs and earnings of tropical tuna vessels based in California. Fish. Ind. Res. 3(1):29-45.

tanker-trailer designed for highway hauling of bait; holding and acclimatizing facilities and much of the labor used in catching the threadfin shad, sending observers on fishing trips, or to conduct dockside interviews, data processing, etc.

BUDGET FOR SHAD EXPERIMENTS

	<u>NMFS</u>	<u>Other sources</u>
<u>Labor costs</u>		
Project leader, 4 months	\$ 5,160	--
Driver for tanker-trailer	1,032	--
7 laborers, 4 months	9,800	\$ 9,800
Diving pay (64 man-days)	800	--
Overtime	<u>3,000</u>	<u>--</u>
	19,792	9,800
<u>Utilities</u>		
Fresh water	--	<u>4,000</u>
<u>Equipment</u>		
Boat trailer, lumber, airstones, anchors, plumbing, bait skiffs, diving gear, tires	--	<u>1,580</u>
<u>Operational expenses</u>		
Oxygen, gasoline, fish food, diving air, repair and maintenance	--	<u>2,576</u>
<u>Miscellaneous and contingency fund</u>	<u>--</u>	<u>2,000</u>
TOTAL	\$19,792	\$19,956

TOTAL BUDGET SUMMARY

	<u>NMFS</u>	<u>Other sources</u>
<u>Project</u>		
Roll on/off	\$10,684	\$29,845
Bait boat transport	12,087	34,000
Threadfin shad	<u>19,792</u>	<u>19,956</u>
	\$42,563	\$83,801

MEMBERS OF AD HOC BAITFISH COMMITTEE

J. Bardach (Hawaii Institute of Marine Biology, UH)
J. Craven (Marine Programs, UH)
J. Davidson (Sea Grant Programs, UH)
A. Gerakas (Pacific Tuna Development Foundation)
F. Goto (United Fishing Agency)
R. Iversen (NMFS, Honolulu)
R. Kinney (Tuna Boat Owners Association)
J. Puffinburger (Hawaiian Tuna Packers)
R. Shomura (NMFS, Honolulu)
M. Takata (Division of Fish and Game, Hawaii State)

Attachment

May 15, 1975

FLOW CHART OF BAITFISH DEVELOPMENTAL ACTIVITIES IN HAWAII FOR 1975

Roll on/off experiments																																																											
Design experiments				Field station construction. Install tanks, plumbing, etc.				Conduct tank experiments with successive lots of baitfish testing parameters:																																																			
								Initial viability								Update economic analysis of roll on/off																				Roll on/off																							
								Handling methods				Dissolved oxygen																																				Initial salinity				Preconditioning				Density of fish			
Tanker modification and maintenance				Shad				Shad fishing and shad use. Fishing tests								Tanker maintenance and ship to Calif.				Trial shipment																																							
Acquire, repair gear																																																											
Bait boat transport																																																											
Contact boat owners. Arrange charter								Provision vessel				Ship bait				Fishing tests with northern anchovy																																											
																Prepare economic analyses of bait boat transport and shad culture																																											
20				31				10				20				30				10				20				31				10				20				31																			
May																																								August																			

[illegible]

August

July

May 30, 1975

F142

Director, Honolulu Laboratory, F142

Heeny S. H. Yuen, Leader, Recreational Fisheries

Trip ReportBackground

Personnel of the Honolulu Laboratory (HL) have attended the annual Hawaiian International Billfish Tournament (HIBT) for the past 13 years and have collected data related to various aspects of the biology of billfishes, of blue marlin primarily. They have also presented workshops, seminars, demonstrations, and exhibits on marine research for public information and education. The scientific and educational activities of HL at the HIBT over the years have, I believe, exerted an influence in the thinking of the sponsoring group. The group has become very conscious of science and education. It has, in fact, recently restructured its organization...accompanied by a name change to Hawaiian International Billfish Association (HIBA)...to support scientific endeavors related to recreational fishing. Funding of research projects and scholarships are examples of the type of support under consideration by the HIBA.

This trip on which I am reporting turned out to be the first support grant of HIBA. Mr. Richard Boone of movie and television fame initially suggested that HIBA send me to the Bay of Islands Billfish Tournament (BOIT). It is my understanding that he in fact financed my trip by a contribution to HIBA for that purpose. Eventually HIBA decided that the trip would include BOIT in New Zealand and the Mini Concours International du Haura Club in Tahiti.

The purpose for my attendance at these tournaments was to promote interest in participating in research on recreational fisheries among fishery scientists, especially those associated with the government.

All my travel arrangements were made by Mr. Peter Fithian, Chairman of HIBA. He organized and led a group of sports fishermen from Hawaii to compete in both tournaments. I traveled with this group which numbered 12 including Mr. Fithian and myself.

Itinerary

March 3	- Departed Honolulu.
4	- Arrived Auckland (1 day lost in crossing date line).

- March 5-7 - In Wellington, conferred with various scientists.
- 8-15 - In Russell, attended Bay of Islands Billfish Tournament.
- 15 - Departed Russell.
- 14 - Arrived Papeete (1 day gained crossing date line)
- 15-18 - In Papeete, attended Mini Concours International du Haura Club.
- 18 - Departed Papeete.
- 19 - Arrived Honolulu.

Activities

I engaged in two types of activities to accomplish my purpose. One was meeting and conferring with fishery scientists. The other was examining the catch and monitoring the activities of the tournaments.

In New Zealand I went to the Capitol, Wellington, to confer with biologists of the Ministry of Agriculture and Fisheries (MAF). My visit there was well managed by Mr. Bert Brun, Chief Fisheries Management Officer, who took on the responsibility of making arrangements for me to meet with people in related work.

I conferred with B. T. Cunningham, who is Director of the Management Division of MAF, and B. Brun on various aspects of research in recreational fisheries. I left with the distinct impression that the Management Division would be actively doing research in recreational fisheries in the near future. Slightly over a week later when Mr. Brun appeared at BOIT he proposed a cooperative venture of creating and maintaining a recreational fisheries data center for the Pacific Ocean. The proposal is an indication that the New Zealand Government is ready to get involved far beyond the local level.

The possibilities of using the PEACESAT project as a means of communicating data in the event of a cooperative program was pursued with Doug Gordon of MAF and PEACESAT Terminal Manager Tony Hanley of Wellington Polytechnic.

I had a lengthy discussion with Don York on the acoustolure. As the originator of the device he was unhappy at the shabby product that was manufactured and sold commercially by a company in New Zealand. The commercial item was so bad that some that York had tested had outputs that could not be detected beyond a few meters. He urged experimenting on our own, that is obtaining some high quality equipment and recording the sounds of a school of feeding skipjack tuna for later playback as an attractant. Although the basic idea appears sensible enough some of the figures he mentioned, e.g., a range of 3 miles, are not compatible with present acoustic equations. Mr. York took me on a field trip outside

of the Bay of Wellington to demonstrate the acoustolure but the water was too choppy to get to the area of the fish schools. He demonstrated convincingly, however, that the acoustolure attracted and held the dolphin, Delphinus delphinus.

Don York, furthermore, presented papers and charts on the hydrographic conditions of the Bay of Islands area to me to provide me with background material for BOIT.

Other fisheries personnel I had discussions with in Wellington were: David Eggleston, Len Tong, Don Coombs, and Gavin James of the Research Division of MAF; and John Moreland of the Wellington Museum.

In Tahiti my scientific conversations were with Mr. Philippe Siu, a dynamic, young biologist with the Tahitian Government. He expressed a definite interest in carrying on research on large game fishes with or without the support of his government.

At both tournaments all the fish caught were measured and examined. Data recorded were: species, length, weight, sex, stage of maturity, the number of various food items found in the stomachs, and observations of anything noteworthy about the specimens. The catch at BOIT consisted of two striped marlin, one blue marlin, five mako shark, and one hammer-head shark. In Tahiti five blue marlin and four yellowfin tuna were caught.

In the New Zealand tournament radio reports from each of the 22 competing teams were scheduled for three times daily - 10 a.m., noon, and 3 p.m. Team identity, fishing area, number of strikes, hookups, and fish boated were reported. Data from all radio reports were recorded. In Tahiti government regulations forbade radio reporting.

In New Zealand two of the five scheduled fishing days were cancelled because of high winds. As mentioned earlier 22 teams competed in this tournament. The tournament in Tahiti was more modest; 10 teams fished for 2 days.

I was joined on various days by Lew Ritchie, Peter Saul, Kim Walsh, and Bert Brun, all of MAF, at BOIT and by Philippe Siu in Tahiti. They observed my activities and assisted in making and recording observations.

Miscellaneous

Tournament officials John Chibnall of New Zealand and Leo Langomaxino of Tahiti supported me fully. They supplied whatever I requested in equipment and services to get the job done.

While at BOIT I had the opportunity to inspect the records of the Bay of Islands Swordfish Club which date back to 1926. The records are of a quality and quantity that, in my opinion, they can be processed for information, e.g., growth rate of the striped marlin. There are probably other clubs throughout the Pacific Ocean with similar types of records.

One of the obvious shortcomings of the records of the Bay of Islands Swordfish Club...and this would probably be true of the records of other clubs...from a fishery biologist's point of view was the lack of data on fishing effort. I think that the climate is such that with the proper approach and presentation a logbook system to get these data recorded would be universally accepted.

Finally, although my enjoying the trip was not one of the purposes of the trip, I did that, too.

cc: Office of International Fisheries, F4

MAY 19 1977

A SUMMARY OF ENVIRONMENTAL AND TUNA FISHING INFORMATION
OF THE U.S. TRUST TERRITORY OF THE PACIFIC ISLANDS

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June 1975

This is a draft report distributed for information only.
It will not be published in the present form and should not be
cited in the literature.

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ABSTRACT

This paper provides a historical background and description of the islands within Micronesia and reviews much of the published information available on the climate, oceanographic climate, planktonic surveys, and tuna fisheries development in that region. Pre-World War II skipjack tuna, Katsuwonus pelamis, landings by the Japanese reached 33,000 metric tons (MT) in 1937. Attention is focused on the postwar development in the fisheries for skipjack tuna in Palau and by the Japanese southern water pole-and-line fleet, which landed 51,000 MT in 1971. The potential for further development within Micronesia is also discussed.

INTRODUCTION

The United States Trust Territory of the Pacific Islands and Guam are situated within reach of some of the most productive tuna fishing grounds in the world, e.g., off the eastern and southern coasts of Japan and around Papua New Guinea. The Trust Territory and Guam, however, are in a paradoxical situation; although they are constantly striving for ways to broaden their economic bases, they are not in a position to take full advantage of the fishery resources within their waters.

In sharp contrast is the tuna fishery in the eastern Pacific, where fishing pressure on yellowfin tuna, Thunnus albacares, has to be relieved. The fishermen in the eastern Pacific, therefore, must supplement their yellowfin tuna catches by fishing on tuna stocks capable of sustaining greater fishing pressure. Among the possibilities is the development of fisheries for skipjack tuna, Katsuwonus pelamis, yellowfin, and bluefin tunas, T. thynnus in the central and western Pacific Ocean.

For the ready reference of American tuna fishermen, it would be most useful to bring together a review of much of the published information available on the environment and tuna fishing in the Trust Territory region. Throughout this report, the words "Micronesia" and "Micronesian" are used to refer to both the Trust Territory and Guam and all the peoples within their boundaries.

HISTORICAL BACKGROUND

Micronesia has a varied and interesting history. In brief, the first contact with the islands of Micronesia by Europeans occurred during the 1500's, first by Magellan and then other occasional explorers (Nathan Associates, 1966). Although most of the islands had no additional contact in the centuries following, the Spanish continued to exert their influence in the Marianas. With the expansion of the copra trade, many islands within the Carolines also received attention and there was strong competition among traders of different nations from about 1875 to 1900.

German, Portuguese, British, and American vessels entered the competition to buy copra in Micronesia (Nathan Associates, 1966). In the last decade of the 19th century, however, the German traders achieved a position of dominance throughout the Carolines and Marshalls. They entered into an agreement with the high chiefs which gave Germany a protectorate over all the Marshalls. In 1899, after the Spanish-American War, the Germans bought from Spanish control all the Micronesian islands except Guam, which became a United States possession.

With the German administration came economic growth and political stability to Micronesia (Nathan Associates, 1966). Copra production increased and western goods became available to the Micronesians. The Germans also had some success in formalizing land ownership. Tools, new food products, and clothing were introduced and the mission schools that were established taught the Micronesians about the outside world.

Japan entered the copra trade on a small scale in 1889 but by 1907 was a significant influence within Micronesia (Nathan Associates, 1966). Entering World War I against Germany, Japan immediately proceeded to occupy the islands of Micronesia; in 1920, she obtained a mandate over these islands from the League of Nations.

In the 1920's and 1930's, Japan fully exploited the resources in Micronesia (Nathan Associates, 1966). Agricultural, fisheries, manufacturing, and processing industries were established with Japanese capital and management. Labor was imported from mainland Japan, Okinawa, and Korea. But with the intensification of war with China in the 1930's, Japan started a military buildup in Micronesia in preparation for World War II. Japanese and Okinawan immigrants outnumbered the Micronesians on larger islands where most of the military activities were concentrated. The Micronesians, however, participated at the fringes of these activities by taking advantage of the opportunity to sell various commodities to the immigrant population.

Despite the self-interest of the Japanese administration, the Micronesians reaped considerable benefits (Nathan Associates, 1966). Under the Japanese, the money economy replaced the traditional barter and gift exchanges and most of the people on the major islands became accustomed to a variety of manufactured and processed goods and many types of services. Schools taught the Japanese language to both Micronesian and Japanese immigrant children.

In 1944, the U.S. Armed Forces began occupying the islands of Micronesia (Nathan Associates, 1966). As a result of the intense fighting, villages on those islands where the Japanese established military bases were completely demolished. Not only the villages and business establishments but also most of the infrastructure--roads and causeways, electric and water systems, harbor and other waterfront facilities--were destroyed.

The U.S. Commercial Company, a subsidiary of the Reconstruction Finance Corporation, was assigned the task of supplying trade goods and reviving production and trade of copra, handicrafts, and other local goods after the American occupation (Nathan Associates, 1966). In 1947, the former mandated islands were established as a trusteeship under the United Nations (U.N.) Trusteeship Council and the U.S. was named trustee. The U.S. Navy Department established a civilian administration to manage the trusteeship.

The Trust Territory Government was established in 1951 and became a part of the Office of Territories of the U.S. Department of the Interior (Nathan Associates, 1966). Most of the Marianas, however, were transferred back and kept under U.S. Navy administration until 1962, at which time all the islands of the Marianas (excluding Guam) returned to the jurisdiction of the Trust Territory Government. Saipan and Tinian in the Marianas were virtually sealed off from the rest of the world from 1953 to 1962 because they were top security areas for the U.S. Navy (Tudor, 1972).

Because the limited financial resource of the Trust Territory Government was spread very thin, postwar recovery was very slow (Nathan Associates, 1966). Some progress was made in expanding the copra trade and agricultural production. In general, there was a settling down and adjustment of the Micronesians to their new economic and political environment under the Americans. An increased budget in 1962 brought a new buildup of schools, hospitals, and other facilities. Incomes increased and public services, particularly health and education, were rapidly expanded. Based on increased money flow, more Micronesians were employed by the government and there were more opportunities for creation and expansion of small businesses.

Divided into six districts--Palau, Yap, Truk, Ponape, Marshall Islands, and Mariana Islands--the Trust Territory is administered by the U.S. Department of the Interior through a High Commissioner who is headquartered at Saipan (Tudor, 1972). Each district, in turn, has a District Administrator, who is the immediate representative of the High Commissioner and who acts as the executive of the district government, administering the laws passed by his district's legislature.

DESCRIPTION OF THE AREA

The 2,141 individual islands within the Trust Territory, scattered in clusters over an expanse of ocean of some 3 million sq mi (7.8 million sq km) or about the size of the continental United States, make up 97 distinct island groups in three archipelagoes--the Mariana, Marshall, and Caroline Islands (Trust Territory of the Pacific Islands, 1956; Nathan Associates, 1966). With a combined land area of 706 sq mi (1,828 sq km), the territory extends about 1,140 mi (2,112 km) from Farallon de Pajaros at the upper tip of the Mariana chain (lat. 20°32'N) to Kapingamarangi (lat. 1°04'N) in the Carolines (Figure 1) (Trust Territory of the Pacific Islands, 1956). East to west, it spreads over roughly 2,400 mi (4,450 km) from Mili atoll in the Marshalls to Tobi in the Western Carolines. Beyond the territory's boundaries are Malaysia to the west, Melanesia ("black islands") to the south, and Polynesia ("many islands") to the east.

Figure 1.--The Mariana, Caroline, and Marshall Islands (U.S. Department of State, 1972).

Early explorers called the islands within the territory "Micronesia" meaning tiny isles (Trust Territory of the Pacific Islands, 1956). But the classifications "Trust Territory" and "Micronesia" are not entirely synonymous. There are two atolls--Nukuoro and Kapingamarangi--which lie farthest south near the equator that are considered Polynesian rather than Micronesian. The distinction is based not only on geographic location but also on ethnological factors.

Guam, ceded by Spain to the United States in 1898, is part of Micronesia but not of the Trust Territory (Trust Territory of the Pacific Islands, 1956). It has its own civil administration with a governor and elected congress.

The islands of Micronesia vary in size from small strips, some of less than an acre to large, high islands with up to 100 sq mi (260 sq km) or more of land area (Nathan Associates, 1966). Among the larger ones are Babelthuap (153 sq mi or 396 sq km) in the Palau group and Ponape (120 sq mi or 334 sq km) (Trust Territory of the Pacific Islands, 1956). The elevation of the islands varies considerably; low-lying coral atolls may be only 6 ft (2 m) above sea level whereas others such as Agrihan Island in the Marianas rise to 3,166 ft (965 m). Less than 20 of the islands are considered large enough to support sizable population concentrations (Nathan Associates, 1966). Only about 100 are large enough to support any permanent population.

MARIANA ISLANDS DISTRICT

The Mariana Islands District, shown in Figure 2, consists of 13 islands and one group of 3 islands called Maug (Tudor, 1972). The islands stretch north from Guam for about 350 mi (648 km). Guam, however, has been a U.S. territory since 1898 and is not included in the Trust Territory. Among the islands in this group, only Rota, Tinian, Saipan, Anatahan, Sarigan, Alamagan, Pagan, and Agrihan are inhabited.

The total land area in the group is about 184 sq mi (477 sq km). More than half of this area, however, comprises three principal islands--Saipan (47 sq mi or 122 sq km), Tinian (39 sq mi or 101 sq km), and Rota (33 sq mi or 85 sq km) (Trust Territory of the Pacific Islands, 1965). Unlike the Carolines to the south, which are predominantly coral islands, the Marianas are all high volcanic islands (Tudor, 1972). Of nine small volcanic islands in the northern portion of the chain, Pagan, Asuncion, and Farallon de Pajaros are still active volcanoes (Bowers, 1951). The southern islands are larger, coral-capped, terraced, and fringed with coral reefs.

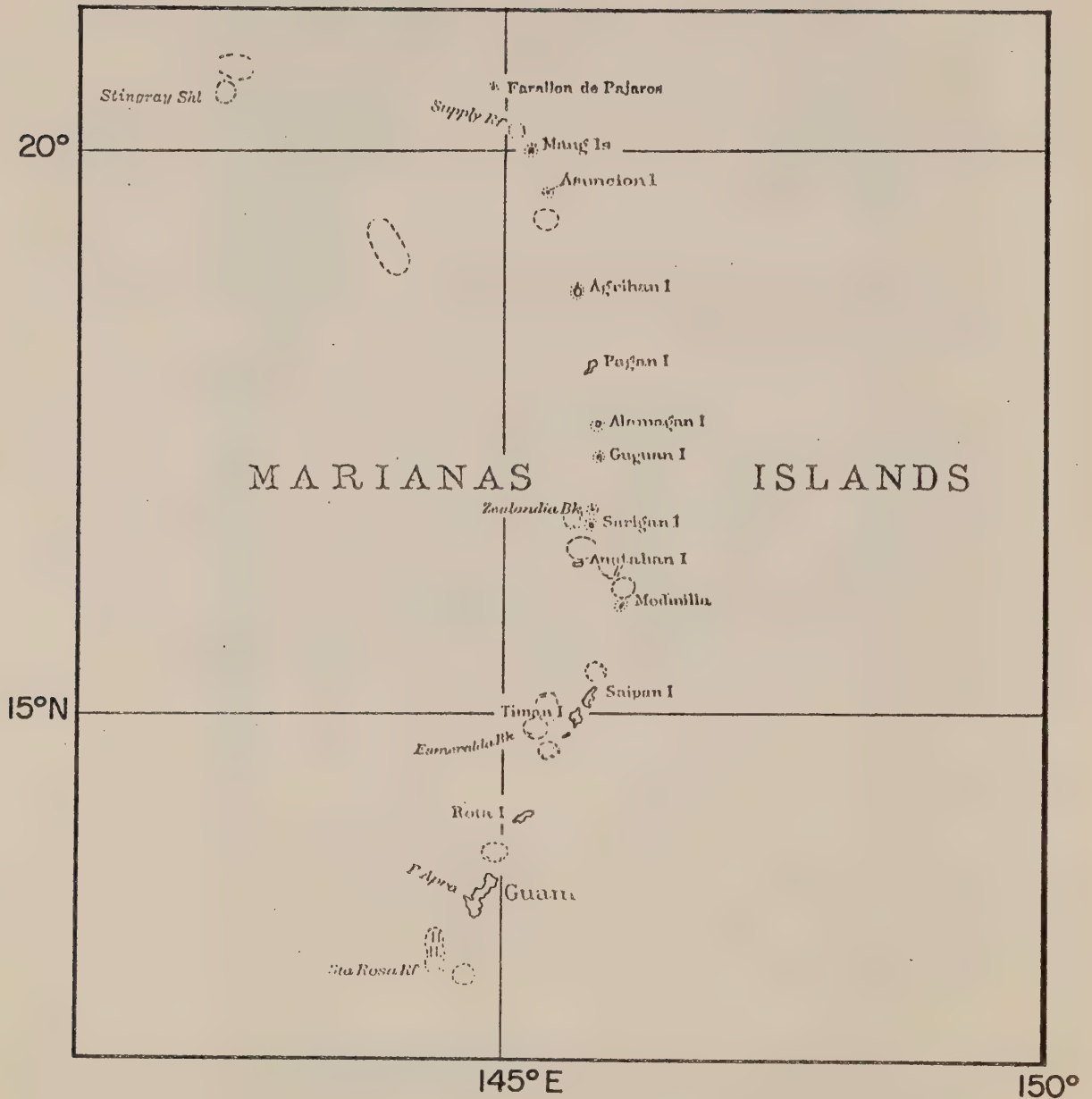


Figure 2.--The Mariana Islands (H. O. 5950).

Of the islands within this district, only Saipan, Tinian, and Rota are of any importance (Tudor, 1972). Under Japanese Mandate, these islands were turned into vast sugar plantations. The southern islands of the chain were strongly garrisoned by the Japanese in World War II.

On Saipan, shown in Figure 3, are located the district administration headquarters at Susupe and the Trust Territory headquarters at Capitol Hill (Tudor, 1972). This island, located at lat. $15^{\circ}12'N$ and long. $145^{\circ}43'E$, is 12 mi (19 km) long by 5 mi (8 km) wide and covers 47 sq mi (122 sq km) (Bowers, 1951; Tudor, 1972). The largest island in the district, Saipan, has a lagoon along its west coast while the land area divides itself into four surface regions. There is a rugged northern upland which covers about two-thirds of the island, a southern plateau, a coastal lowland on the southwest, and Kagman Peninsula.

Tinian, to the south of Saipan and separated from it by a strait of about 3 mi (6 km), is 10 mi (16 km) long and 5 mi (8 km) wide and has 39 sq mi (101 sq km) of land (Bowers, 1951; Tudor, 1972). The island, shown in Figure 4, has no lagoon like Saipan but is steep with two plateaus separated from each other by a valley that has a northeast-southwest axis. It is located at lat. $14^{\circ}58'N$ and long. $145^{\circ}38'E$.

Consisting of coralliferous limestone on a volcanic base, Rota, shown in Figure 5, is 10 mi (16 km) long and 3 mi (5 km) wide, covering about 32 sq mi (83 sq km). Situated at lat. $14^{\circ}10'N$ and long. $145^{\circ}15'E$, Rota is the only island in the Marianas, besides Guam, that has had a history of continuous occupancy by the Chamorros, the indigenous residents of the Mariana Islands.

GUAM

Guam is situated at the southern extremity of the Mariana Islands at lat $13^{\circ}26'N$ and long $144^{\circ}43'E$ (Tudor, 1972). A territory of the U.S. since 1898, Guam is peanut-like in shape, 28 mi (45 km) long and varying in width from 4 to 8 mi (6 to 13 km) (Bowers, 1951). It is the largest island in the Mariana chain, resembles the others in general formation, and has a land area of slightly over 200 sq mi (518 sq km). The island is divided into two sections, physiographically--a northern plateau and a higher southern mountainous area (Figure 6). The northern plateau is coral-capped, rises 200-600 ft (61-183 m) above sea level and has three low volcanic hills all under 900 ft (274 m) in altitude. A large proportion of the coastline ends abruptly in cliffs.

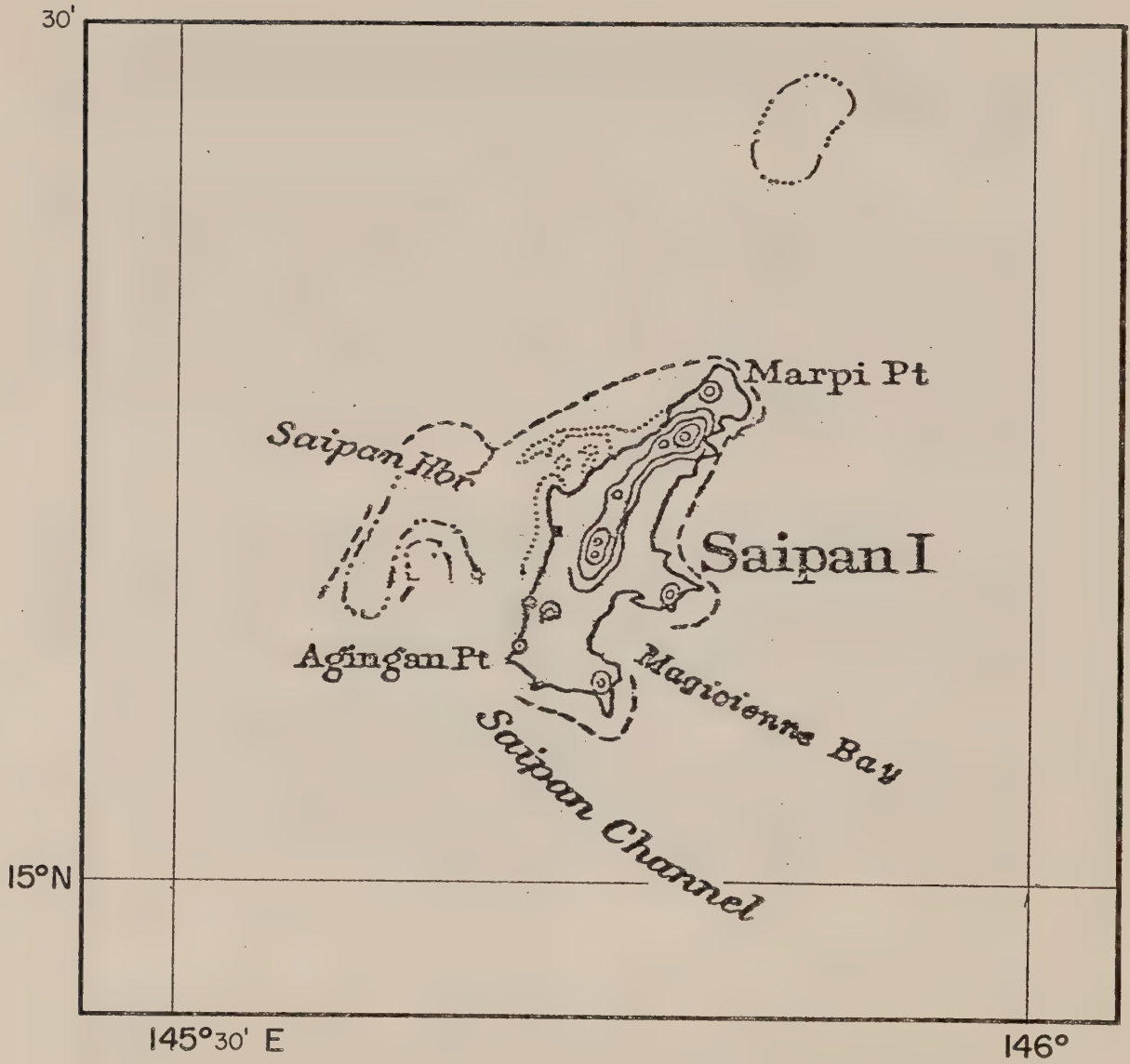


Figure 3.--Saipan Island (H. O. 5360).

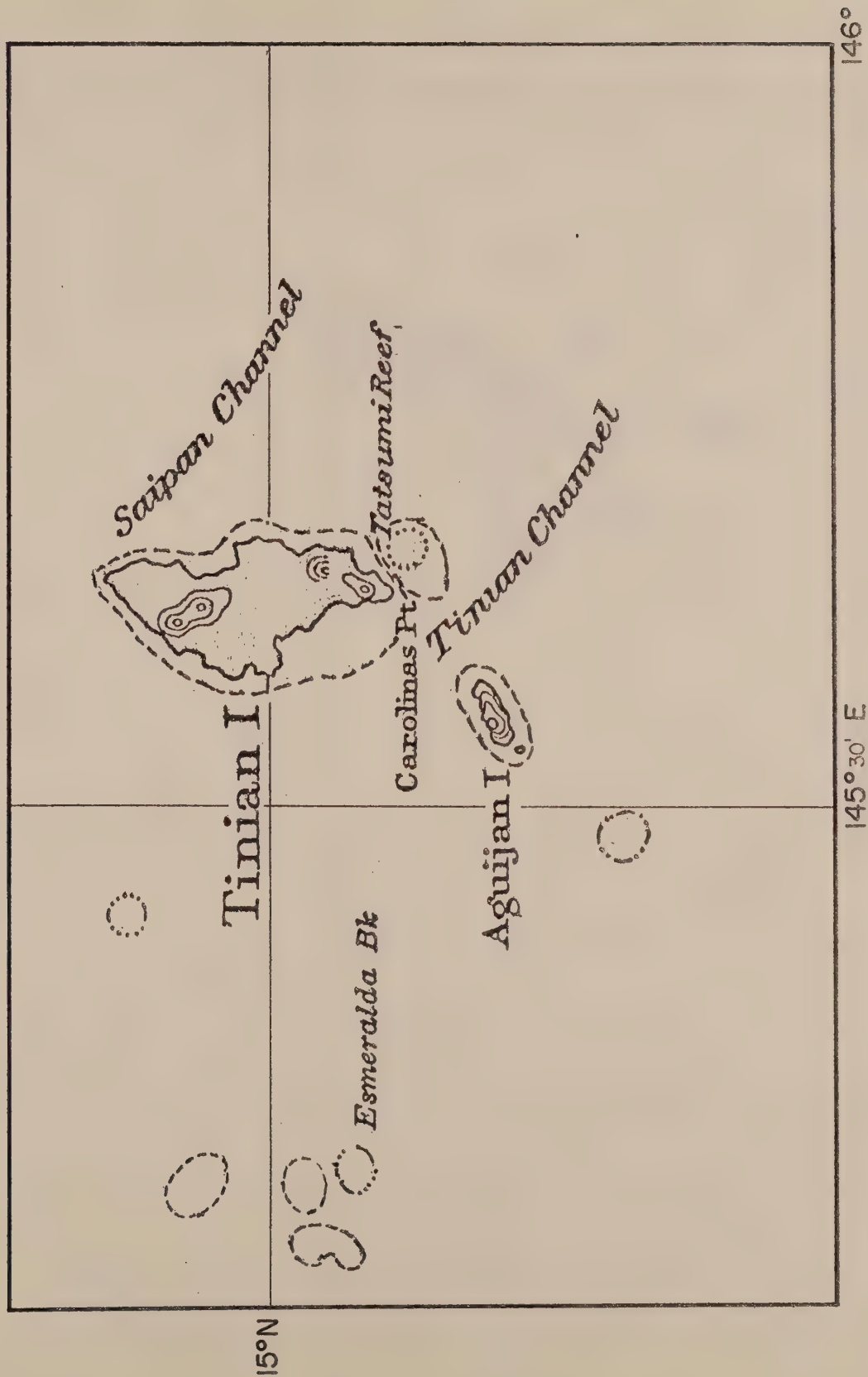


Figure 4.--Tinian Island (H. O. 5360).

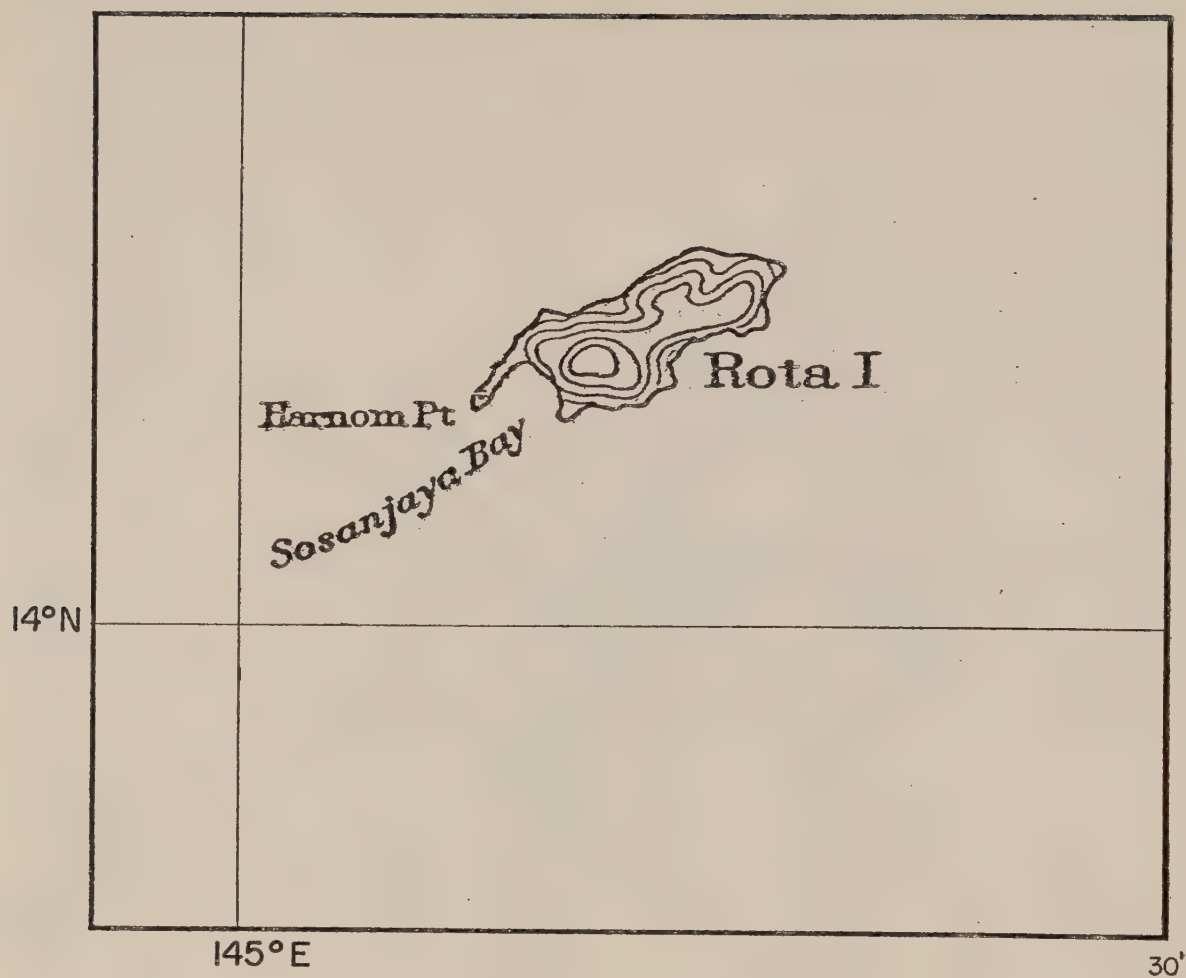


Figure 5.--Rota Island (H. O. 5360).

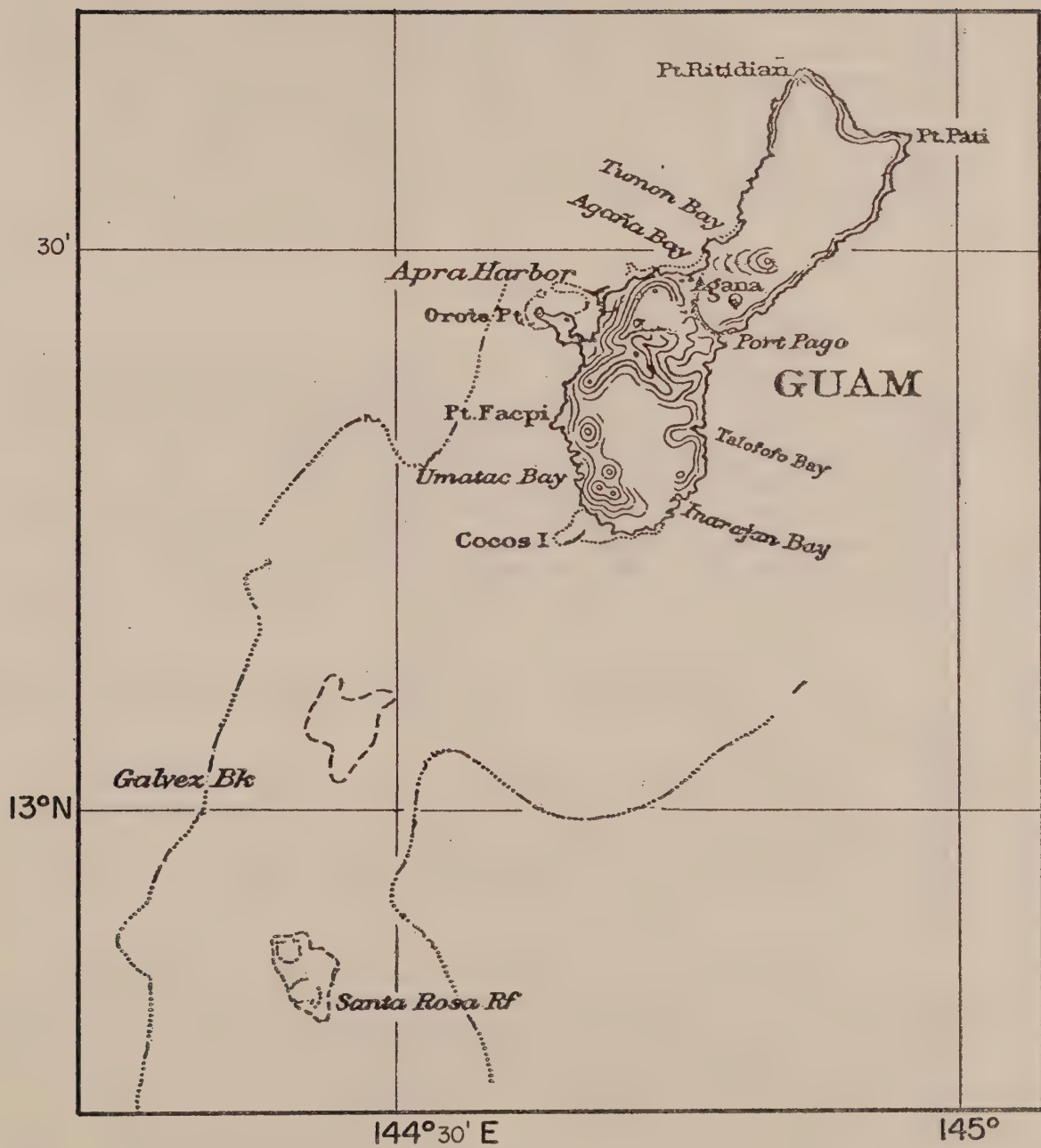


Figure 6.--Guam Island (H. O. 5417).

Guam was under the administration of the U.S. Navy until 1950 when the U.S. Congress enacted the Organic Act which placed the island under a civilian administration responsible to the U.S. Department of the Interior (Kim, 1974). Under this act, the Governor was appointed by the President with the advice and consent of the U.S. Senate. But in November 1970, Guam held its first election for Governor and Lieutenant Governor. Agana, the capital of Guam, is a modern city, having been entirely replanned and rebuilt following its complete destruction during World War II.

MARSHALL ISLANDS DISTRICT

The Marshall Islands, consisting of 28 low-lying coral atolls 5 single islands, and 867 reefs, lie between lat. 5° and 15°N and long. 162° and 173°E and are divided geographically and culturally into the Ratak (sunrise) chain and Ralik (sunset) chain (Mason, 1951; Trust Territory of the Pacific Islands, 1965; Tudor, 1972). Paralleling each other about 130 mi (241 km) apart, the Ratak chain comprises 13 atolls and 2 single islands whereas the Ralik chain is composed of 15 atolls and 3 single islands (Figure 7). Rising not more than a few feet above sea level, the islands have a total area of about 66 sq mi (171 sq km).

The important islands in the district are Majuro, Jaluit, and Kwajalein; Eniwetok and Bikini became well known after they were used in atomic bomb experiments.

Majuro, shown in Figure 8, is regarded as the capital of the Marshall Islands and the district headquarters are located there (Trust Territory of the Pacific Islands, 1965). Situated at lat. 7°05'N and long. 171°08'E, Majuro has an irregularly oval lagoon that measures about 28 mi (45 km) long and 11 mi (17 km) wide (Uchida and Sumida, 1973).

Jaluit, with a lagoon triangular in shape and measuring roughly 30 mi (48 km) long by 12 m (19 km) broad, has three deep passages through which vessels of any size can pass and anchor safely in 25-30 fm (fathoms) (46-55 m) of water (Figure 9) (Tudor, 1972). Jaluit lagoon is more than twice the size of Majuro lagoon. This atoll is located at lat. 6°00'N and long. 169°35'E.

Kwajalein, located at lat. 9°15'N and long. 167°30'E, became well known as a result of war operations (Figure 10). Having good accommodations for shipping, this atoll consists of 90 islets along a reef which encloses a 650-sq mi (1,684-sq km) lagoon, the largest in the world (Tudor, 1972). At present, Kwajalein islet, located at the extreme southern point of this triangular atoll, is a top secret anti-missile base for the U.S. and is under the jurisdiction of the U.S. Navy.

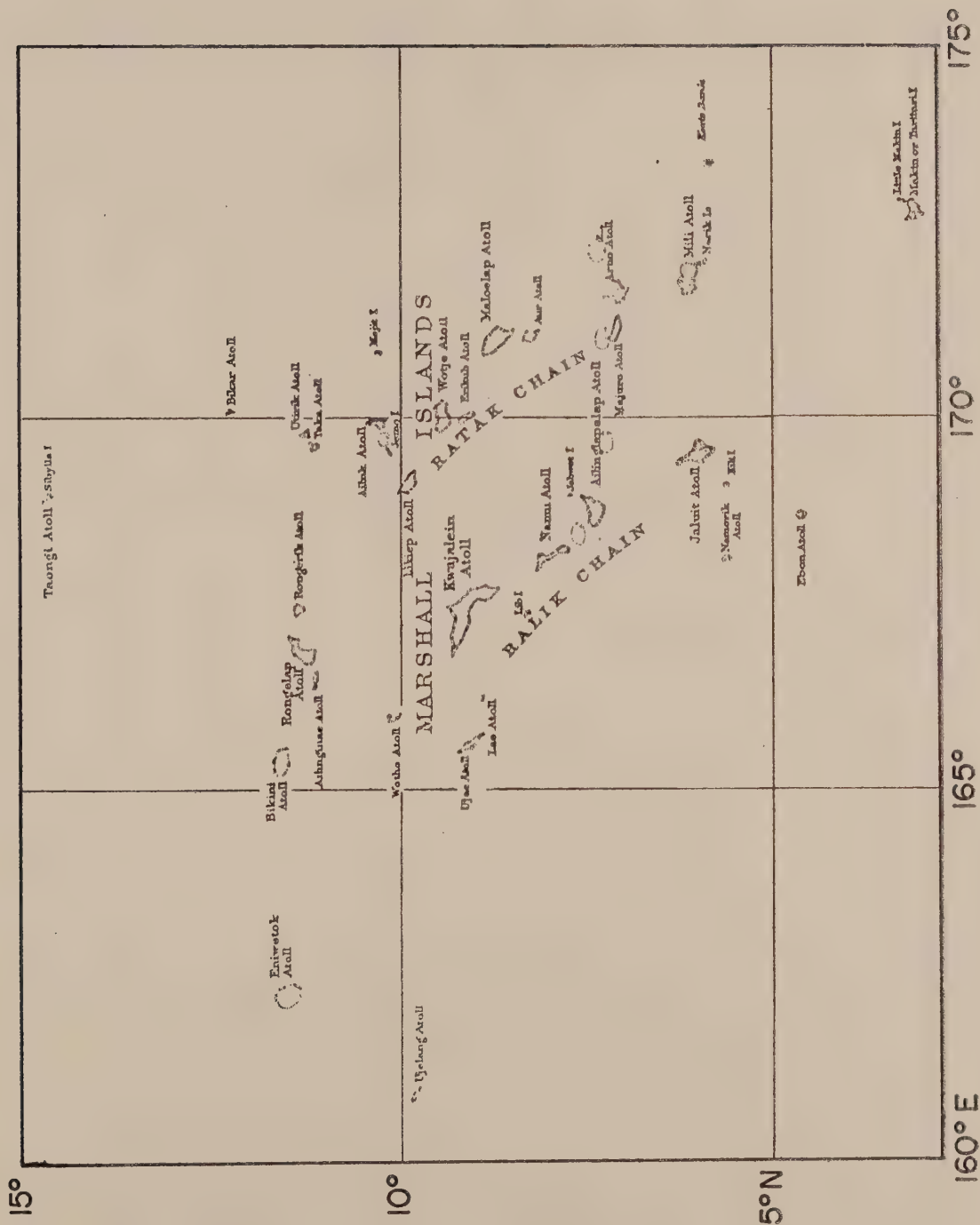


Figure 7.--The Marshall Islands (H. O. 5950).

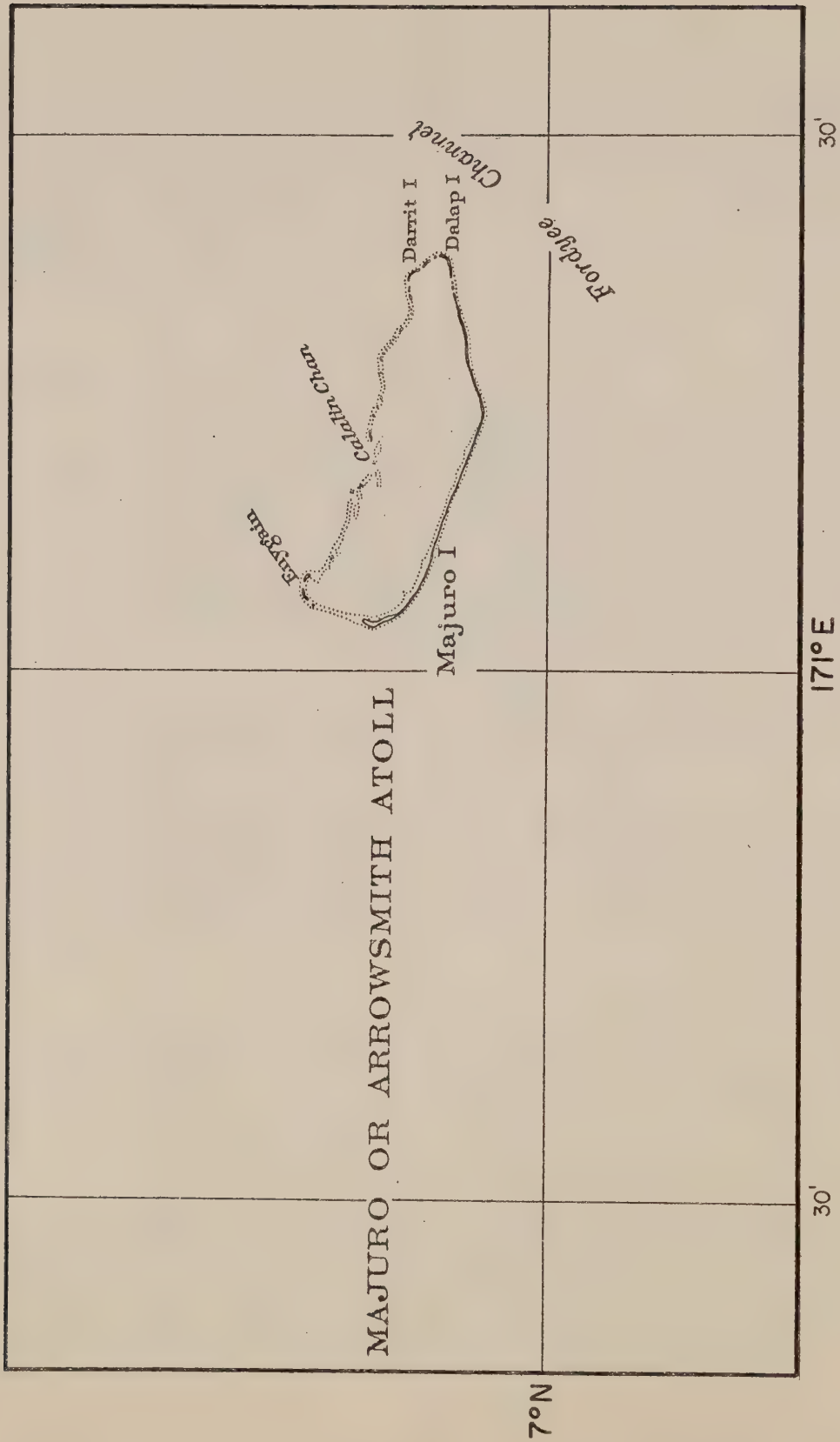


Figure 8.--Majuro Atoll (H. O. 5414).

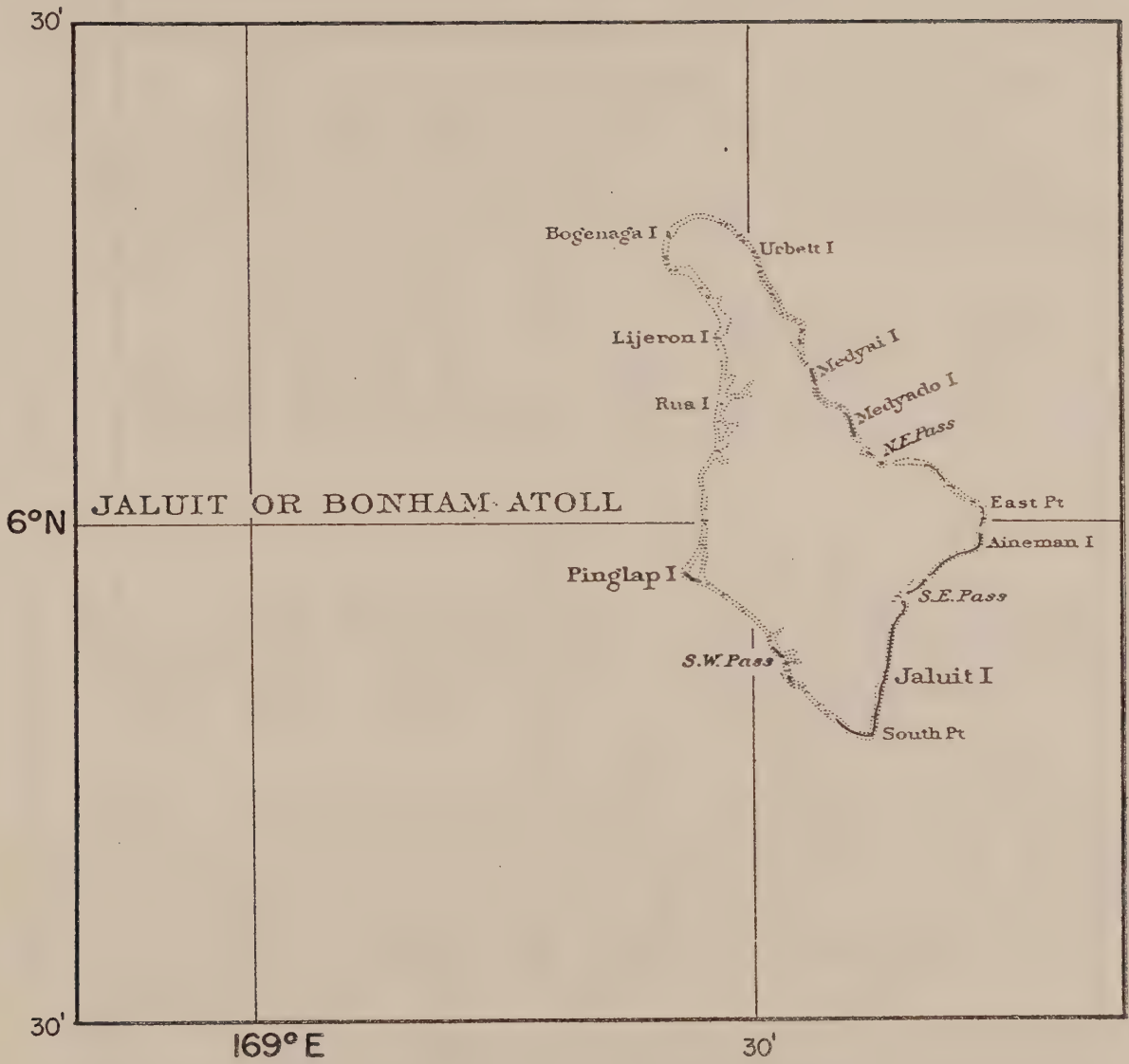


Figure 9.--Jaluit Atoll (H. O. 5414).

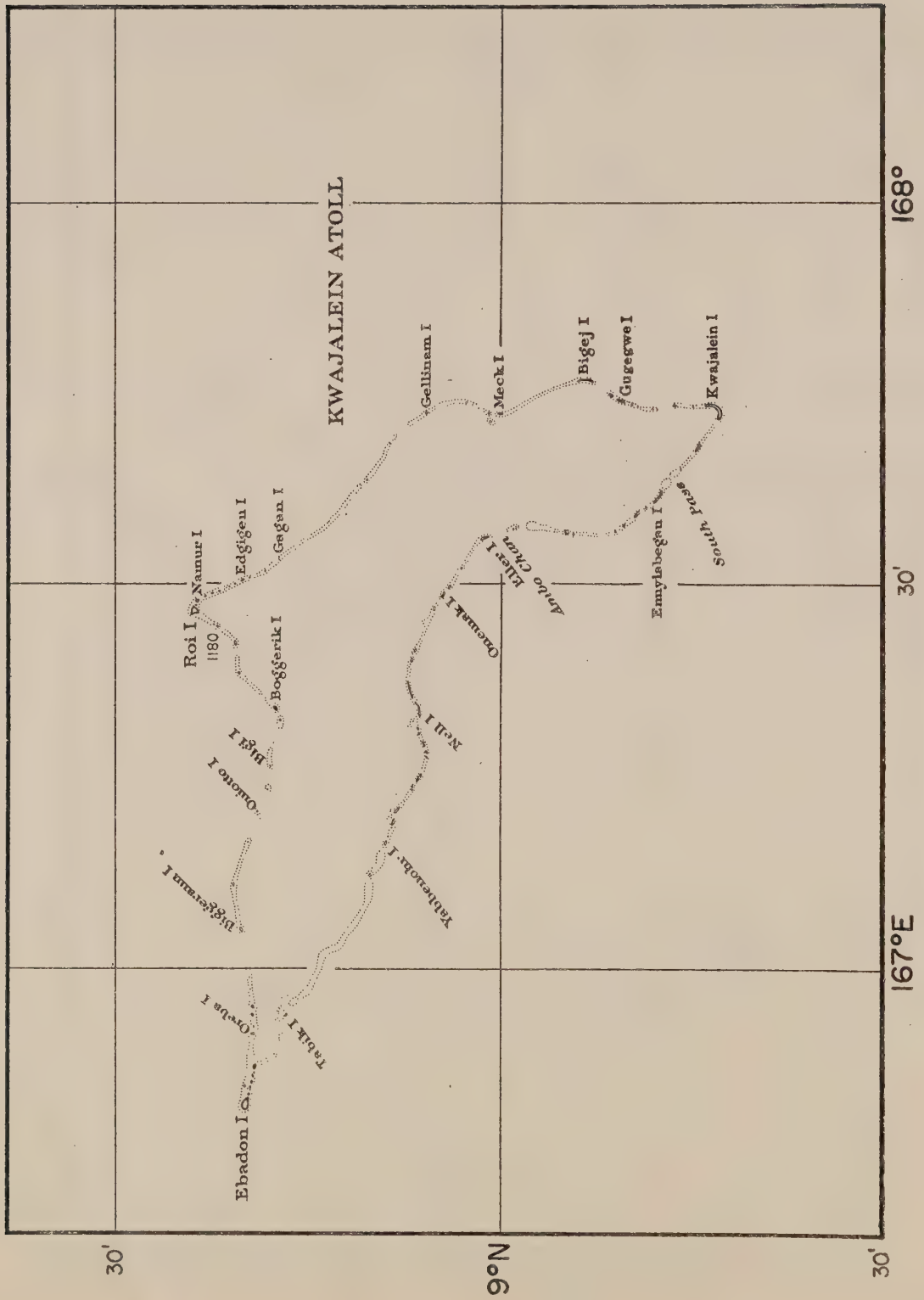


Figure 10.--Kwajalein Atoll (H. O. 5413).

DISTRICTS WITHIN THE CAROLINE ISLANDS

The Carolines lie in a vast chain just north of the equator between lat. 3° - 10° N and long. 131° - 163° E (Figures 11 and 12) (Manchester, 1951). Within the Carolines are 963 islands scattered over 1.3 million sq mi (4.5 million sq km). The total land area, however, is small and estimated to be about 830 sq mi (2,150 sq km). Included are volcanic islands with mountains and streams to tiny palm-clad islets and coral reefs only a few feet above sea level.

Politically, the islands are divided at long. 148° E into the Eastern and Western Carolines (Manchester, 1951). Administratively, the Western Carolines include the Palau and Yap Districts and the Eastern Carolines include the Truk and Ponape Districts. These administrative districts are named after the largest high islands within them.

Palau District

The Palau Islands, shown in Figure 13, comprise 200 islands scattered over an area about 125 mi (232 km) long and 25 mi (46 km) wide (Manchester, 1951; Tudor, 1972). They lie at the westernmost end of the Caroline chain at about lat. $7^{\circ}30'$ N and long. $134^{\circ}35'$ E. The islands are about 700 mi (1,300 km) southwest of Guam.

Rising abruptly from the sea, these volcanic islands are among the most beautiful in Micronesia. The principal islands in the group are Koror, which served as the administrative headquarters under the Japanese regime, Peleliu, and Angaur. Babelthup at the north end of the group is the largest island in the Trust Territory, measuring roughly 27 mi (43 km) long and 8 mi (13 km) wide. It is very fertile, well-wooded, and produces many varieties of tropical fruits and vegetables (Tudor, 1972).

A large barrier reef about 70 mi (113 km) long fringes the eastern shores but widens on the western side of the main islands (Manchester, 1951). The reef is difficult to cross except in a few places. Outside the reef and to the north are the Kayangel Islands, which rise only a few feet above sea level. To the south, Angaur, a raised atoll, is important for its phosphate deposits.

Yap District

The Yap group (Figure 14) consists of four principal islands--Yap, Gagil-Tomil, Map, and Rumung--and about 10 small islands

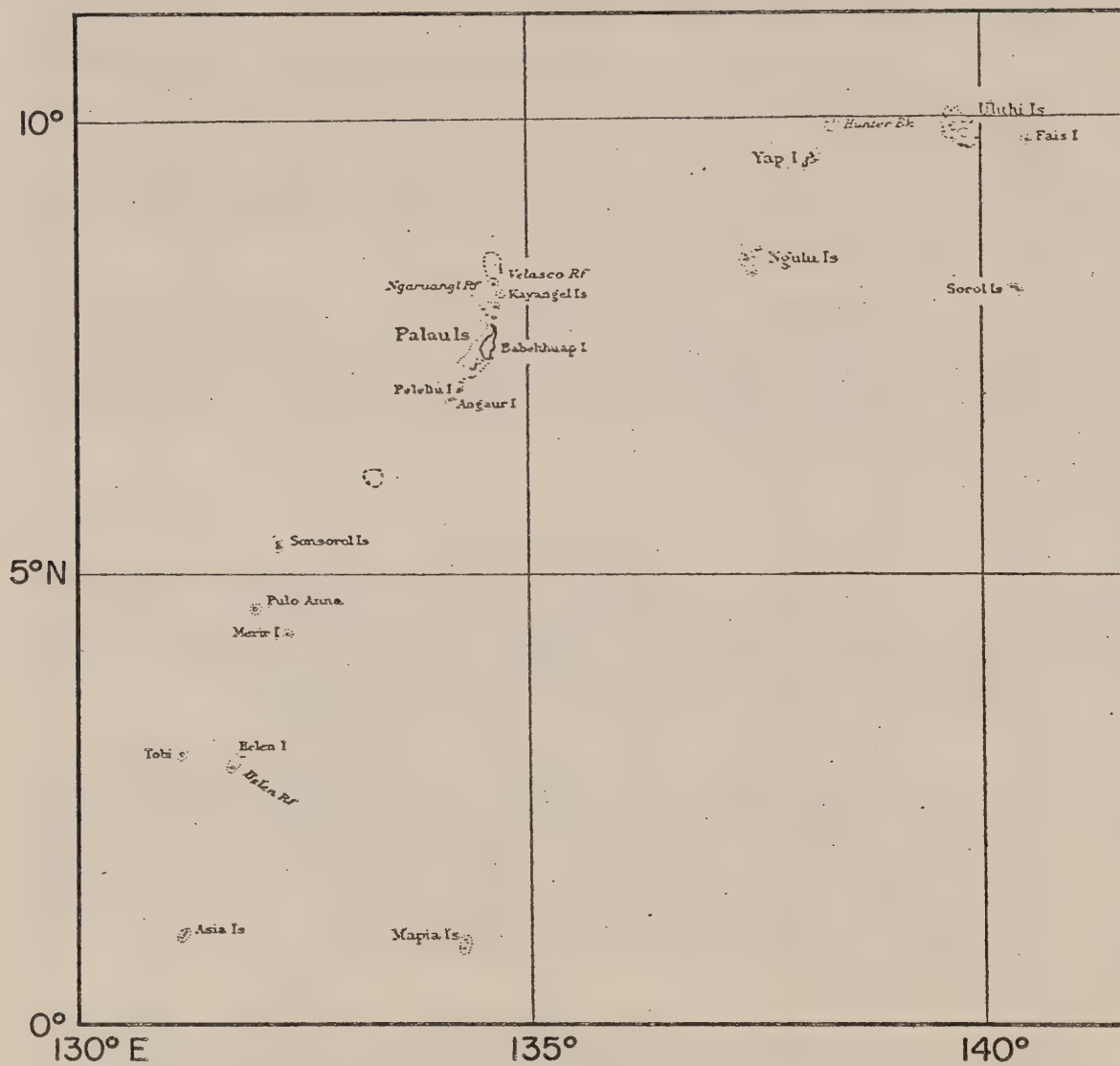


Figure 11.--The Caroline Islands west of long. 142°E (H. O. 5950).

Figure 12.---The Caroline Islands east of long. 142°E (H. O. 5950).

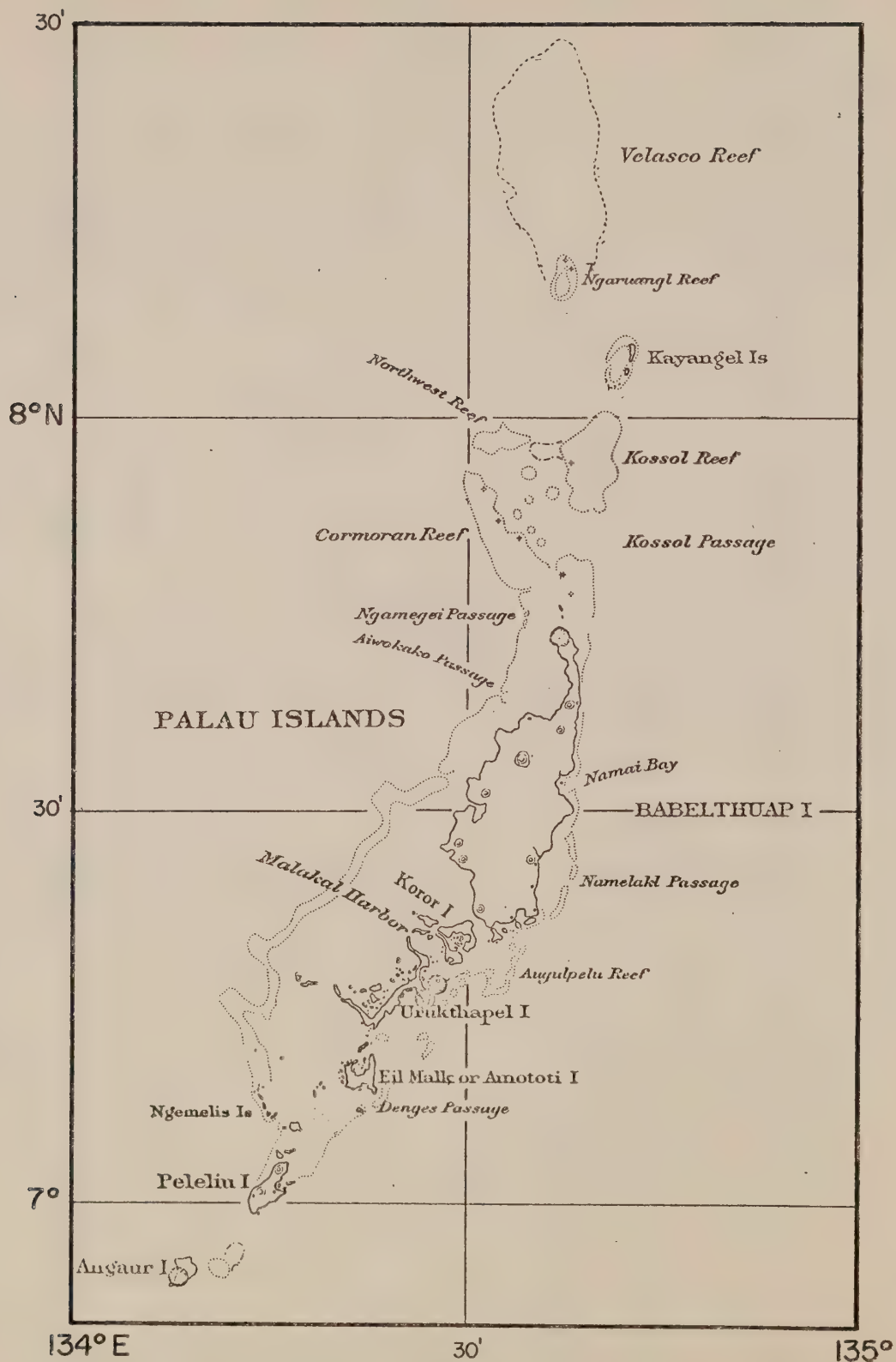


Figure 13.--Palau Islands (H. O. 5418).



Figure 14.--Yap Islands (H. O. 5412D).

(Manchester, 1951; Tudor, 1972). Located between lat. $9^{\circ}25'$ - $9^{\circ}46'$ N and long. $138^{\circ}03'$ - $138^{\circ}14'$ E, the group is situated on a triangular submarine platform and surrounded by a fringing reef. The reef varies in width from 0.5 mi (1 km) to 2 mi (3 km). The islands enclosed by the reef stretch 16 mi (26 km) long and 8 mi (13 km) wide. The main islands are narrowly separated from each other by lagoons. Land area has been estimated to be about 39 sq mi (101 sq km).

Yap is hilly and covered with magnificent forests of coconut and areca palms, bamboos, and crotons (Tudor, 1972). The largest of the individual islands in the group, Yap is about 12 mi (19 km) long and 3 mi (5 km) wide. The highest elevation is 585 ft (178 m) above sea level.

The Yap District headquarter is located in Colonia. Island groups included in the Yap District are Ulithi and Woleai, among others.

The Yapese are dignified, sensitive people who have retained many of their old customs and beliefs (Trust Territory of the Pacific Islands, 1965). Their stone moneys, bulky grass skirts, and loin cloths, have become the best known among the indigenous customs of Micronesia. Their famous stone moneys with holes through their centers were brought by sailing vessels from Palau and represent wealth.

Truk District

Truk District consists of Truk proper, 12 low-lying atolls, and 2 low islands. The Truk group, located 650 mi (1,204 km) southeast of Guam between lat. $7^{\circ}07'$ - $7^{\circ}41'$ N and long. $150^{\circ}04'$ - $151^{\circ}22'$ E, is commonly referred to as an "almost atoll" or "complex atoll" (Manchester, 1951; Trust Territory of the Pacific Islands, 1965). The group, shown in Figure 15, resembles a typical atoll in that it has a great barrier reef varying from 30 to 40 mi (48 to 64 km) in diameter, but there is a cluster of large, high islands inside the lagoon, the most important of which are Moen, Dublon, Fefan, Uman, Udot, Fanapenges (Falabeguets), and Tol. Tol is the largest of the islands and has the highest elevation at 1,483 ft (452 m). Elevation of the others varies from 950 ft (290 m) to a little over 1,000 ft (305 m). The lagoon is about 820 sq mi (2,124 sq km) whereas the land area of all the islands in the group is only about 39 sq mi (101 sq km) (Manchester, 1951).

There are 20 passes piercing the encircling reef, but only 4 are navigable. There are several fine harbors and anchorages within the reef, the chief one being enclosed by Dublon, Fefan, and Uman islands. Of the 40 islets on the encircling reef, only 1, Pis (pronounced peace) is permanently inhabited.

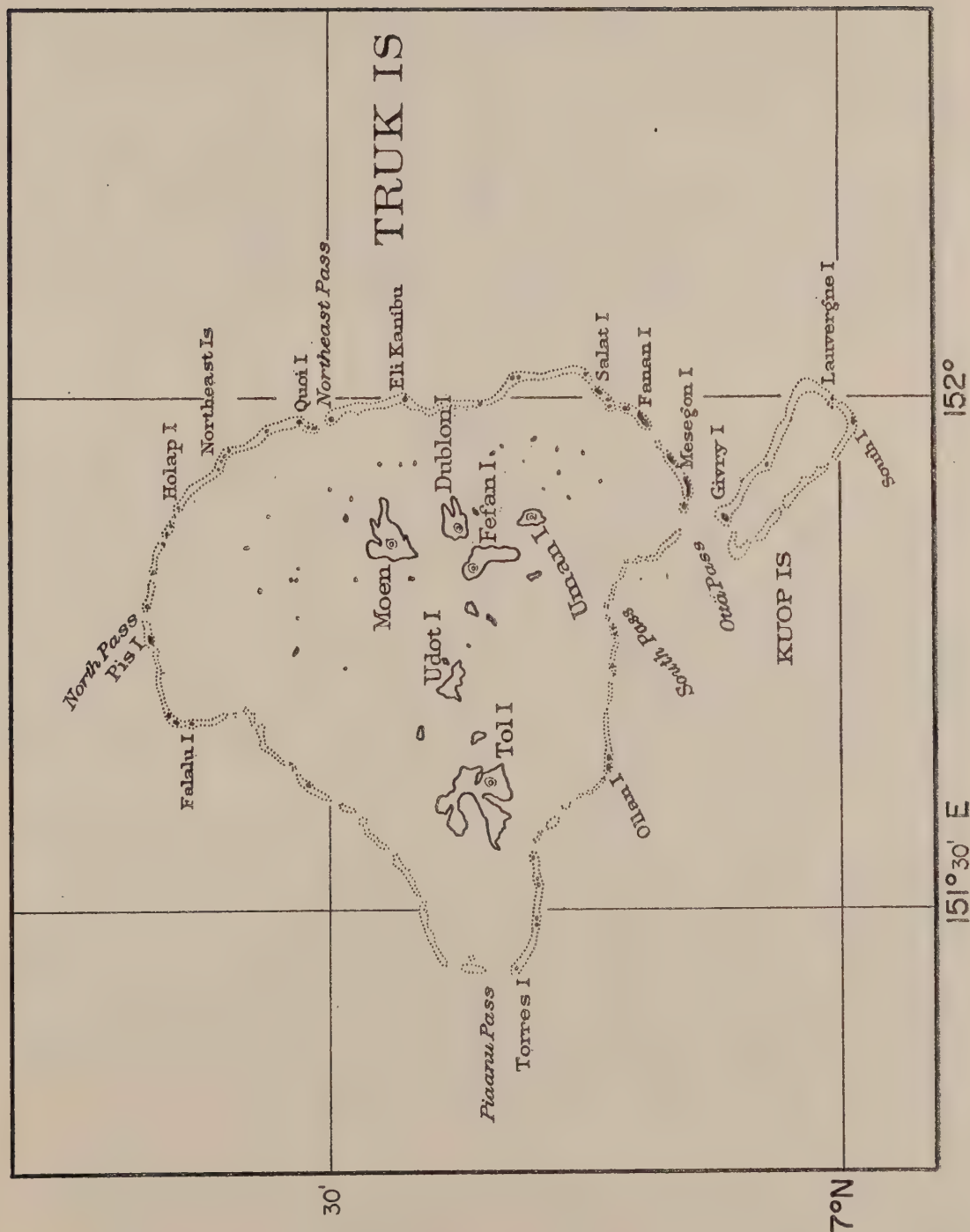


Figure 15.--Truk Islands (H. O. 5416).

Truk is actually a summit of a volcanic dome that rises from a submarine plateau (Manchester, 1951). The islands of the eastern part of the plateau are fairly stable, but there has been some subsidence as evidenced by drowned river valleys.

The most northerly atoll of the district is Manonuito, which is the world's second largest atoll (Tudor, 1972). Lying near the eastern side of the district are East Fayu and Hall Islands. To the west of Truk are Pulap and Puluwat and directly south lie Kuop, Nama, and Losap atolls. Near the district boundary to the southeast are Namoluk atoll and Mortlock Islands, comprised of about 100 islands arranged in three groups called Etal, Lukunor, and Satawan.

Ponape District

Ponape District, the most eastern among districts within the Carolines and including all islands east of long. 154°E , contains the high islands of Ponape and Kusaie and eight atolls (Manchester, 1951; Tudor, 1972). Ponape Island, located at lat. $6^{\circ}53'\text{N}$ and long $158^{\circ}14'\text{E}$ and shown in Figure 16, is a volcanic dome similar in origin to Truk but less advanced in subsidence. It rises gradually from the sea to a height of 2,579 ft (786 m). Second in size in the territory--only Babelthuap in the Palaus is larger--Ponape is about 14 mi (22 km) from north to south and 16 mi (26 km) from east to west. With a land area of 129 sq mi (334 sq km), the island is surrounded by 25 small islands of both coral and volcanic origin. This entire complex is surrounded by a barrier reef that encloses a narrow lagoon.

Colonia is the main town in Ponape and is the seat of the district administrative headquarters (Trust Territory of the Pacific Islands, 1965). The district includes the small groups of small islands called the Ant and Pakin groups and Ngatik (Tudor, 1972). Ponape, Ant, and Pakin are collectively known as Senyavin Islands. Isolated in the northwest of the district is Oroluk and about 100 mi (185 km) southeast of Ponape is the Mokil group, which includes Urak, Manton, and Mokil. Southeast of Mokil is the Pingelap group--Pingelap, Takai, and Tagulu--which are close together on one reef. Kusaie, often described as one of the most beautiful islands in the Pacific, is the farthest east of the Carolines.

CLIMATE

The climate in Micronesia can best be described as tropical and uniform. Because there are no large islands included in Micronesia,



Figure 16.--Ponape Islands (H. O. 5415).

the climate is wholly marine to insular, tropical to the south and subtropical on the north (U.S. Weather Bureau, 1943). The mean annual air temperature over southern waters varies only by about 2°F (1°C) whereas over northern waters it is close to 15°F (8°C). Rainfall is heavy usually among the large island groups. Trade winds and monsoons (seasonal winds that blow from continental interiors to the ocean in winter and opposite in summer) exert their influence over Micronesia with a succession of winds much more pronounced over the Marianas and the Western Carolines than over more eastern waters. The reason is that the continental effects lessen with distance and the trades are the predominant winds.

In the sections that follow, detailed discussions of several weather elements are presented.

AIR TEMPERATURE

At sea in the western Pacific, the mean air temperature fluctuates only slightly from 80° to 84°F (27° to 29°C) all the way from the equator to lat. 15°N (U.S. Weather Bureau, 1943). Monthly variation in some areas near the equator scarcely exceeds 2°F (1°C); between lat. 10° and 15°N, the monthly variation may be as much as 4°F (2°C). Between lat. 15° and 20°N near long. 165°-170°E, the variation may be as much as 5°F (3°C) with a January-February average of 77°F (25°C) and that of August-September being 82°F (28°C).

Closer to the Asiatic continent at lat. 20°-25°N between long. 130° and 165°E, the January-March mean is 72°F (22°C) with February usually the coolest month (U.S. Weather Bureau, 1943). July is usually the warmest with temperatures averaging 83°F (28°C), making the annual range about 12°F (7°C). In the eastern sector of this belt between lat. 20°-25°N, the January-March mean is 74°F (23°C) whereas the July-September mean is 82°F (28°C). The annual range, therefore, is only 9°F (5°C), slightly less than to the west.

From lat. 25° to 30°N between long. 155° and 165°E, cooling becomes more apparent in the winter and spring (U.S. Weather Bureau, 1943). The lowest mean temperature, 64°F (18°C), is delayed until March. In summer, the temperature is only 3°F (2°C) lower than that near the equator.

Among the islands all the way from Jaluit at lat. 6°N to Wake Island at lat. 19°N, the mean annual temperature at near sea level ranges between 80° and 82°F (27° and 28°C) (U.S. Weather Bureau, 1943). At the Saipan Observatory, however, which is located 700 ft (213 m) above sea level, there is a record in these latitudes of a mean temperature as low as 78°F (26°C).

The U.S. Weather Bureau (1943) also reported that the monthly means at most stations in the western Pacific do not vary by more than 2°F (1°C) although there are exceptions. One is Saipan, where the February mean is 76°F (24°C) while the June mean is 80°F (27°C).

The mean daily temperature range, obtained as the difference between the annual means of the maximum and minimum temperatures, is 9°-11°F (5°-6°C) (U.S. Weather Bureau, 1943). At Palau, for example, the annual means of the maximum and minimum temperatures are 86° and 76°F (30° and 24°C), respectively. At other stations, they are as follows: Jaluit, 88° and 77°F (31° and 25°C); Ponape, 85° and 75°F (29° and 24°C); and Saipan, 83° and 74°F (28° and 23°C).

WIND DIRECTION AND VELOCITIES

The oceanic wind system between the equator and lat. 25°N consists of the monsoons and the northeast trades (U.S. Weather Bureau, 1943). West of long. 140°E, between the equator and lat. 5°N, the monsoonal succession of winds is fairly well defined. During the winter half of the year the northerlies, which include the westerlies to northeasterlies, are predominant, whereas during the summer half, the southerlies, which include the easterlies to southwesterlies, predominate. Between lat. 5° and 20°N, the northerly monsoon veers into more settled northeast trades from November to May. The summer winds in this region show the influence of the monsoons by turning into southerly and southwesterly winds. Figure 17 shows the average surface wind drift direction over the central and western Pacific Ocean.

Over the Marianas and central Carolines, the influence of the summer monsoon from Asia is insignificant (U.S. Weather Bureau, 1943). The northeast trades are predominant and strong except in summer. Farther eastward, the trades from northeast to east become increasingly dominant throughout the year.

In the latitudinal belt from the equator to lat. 5°N between long. 140° and 170°E, northeast and east winds are the most frequent annual winds (U.S. Weather Bureau, 1943). There is, however, a tendency for the frequency of these winds to increase from west to east. For example, in long. 140°-145°E, northeast and east winds constitute more than 60% of the observations annually. In the winter half of the year, some of the influence from monsoons persists; the result is that north, northwest, and west winds appear temporarily and overcome the trades. In the summer half of the year, the southeast trades cross the equator and partly replace the northeast winds. Although the east wind predominates at this time, southerly trades from southeast to southwest are rather frequent.

AVERAGE SURFACE WIND DRIFT DIRECTION, CONSTANCY AND FORCE

Symbols shown on charts 3 to 7

Prevailing winds move with the arrows

Direction and frequency:

81 percent or more.....→→→→→

61 to 80 percent.....→→→→→

41 to 60 percent.....→→→→→

25 to 40 percent.....→→→→→

Average velocity:

▨ indicates predominance of Beaufort 0-3 (0 to 10 knots), ▨ indicates stronger winds, Beaufort 4 (11 to 16 knots) and higher, dominant 60% or more of the time.

CHART 3.—February.

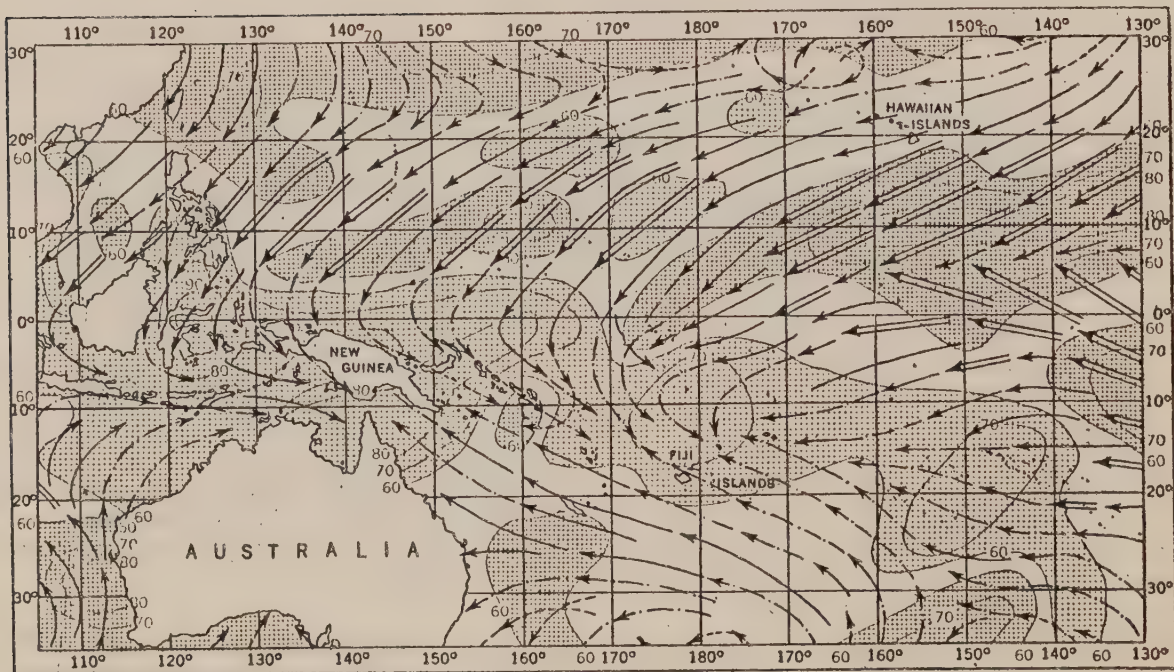


Figure 17.--Average surface wind drift direction, constancy, and force in the western Pacific Ocean (U.S. Weather Bureau, 1943).

CHART 4.—May.

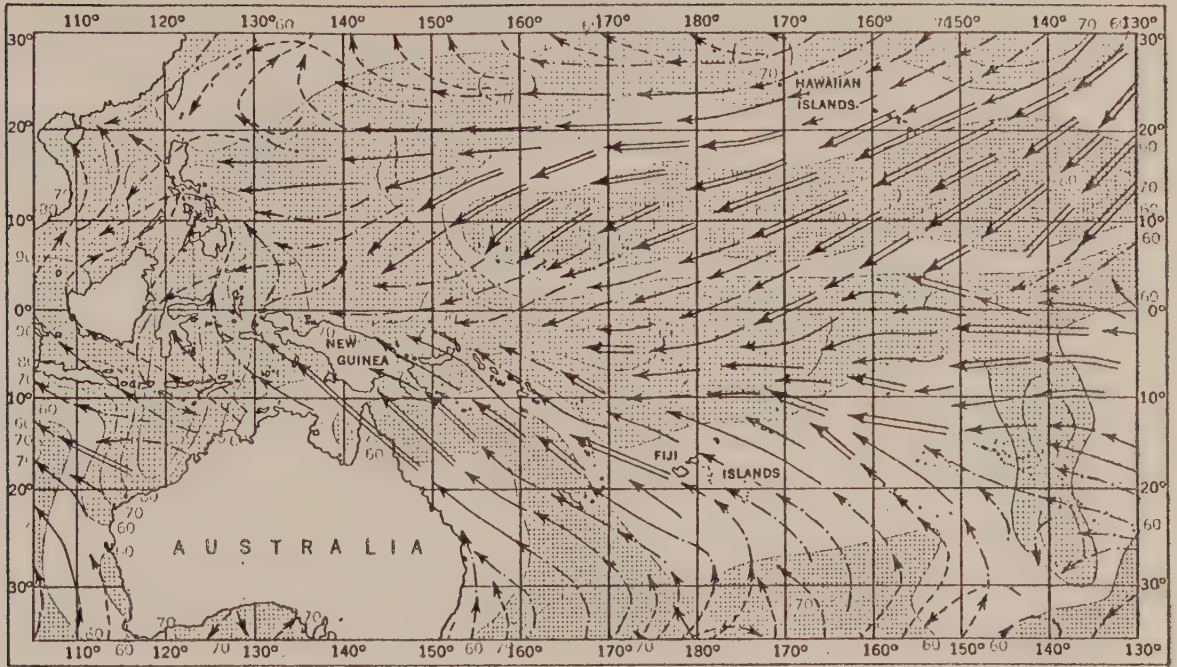


CHART 5.—July.

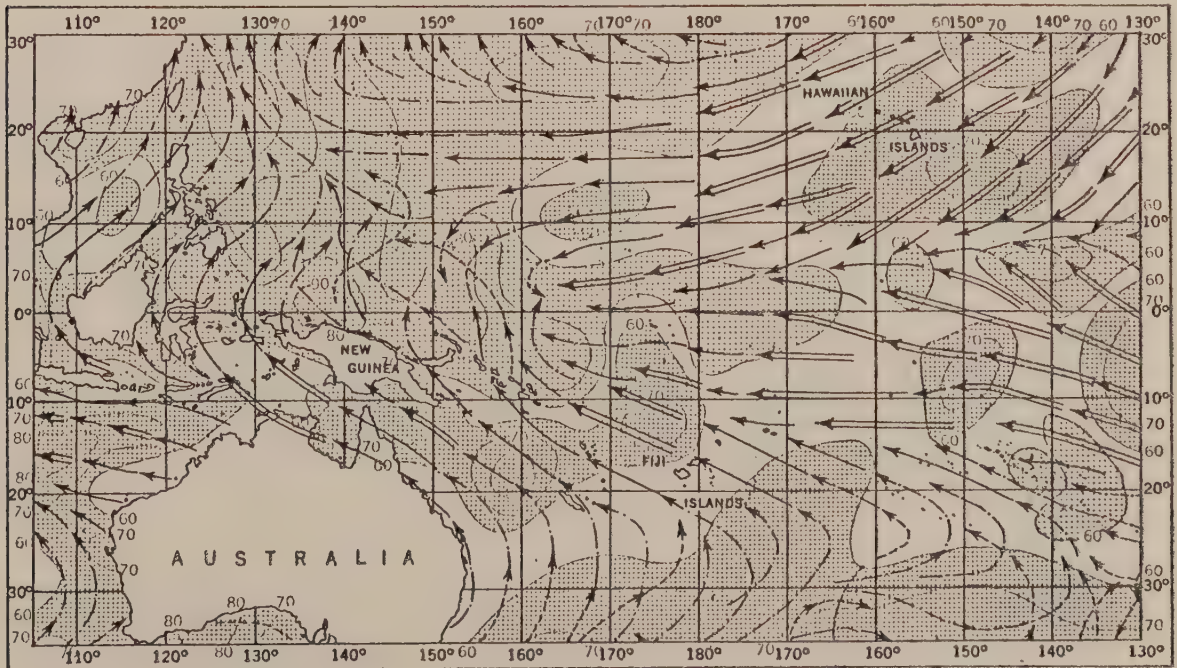


Figure 17.—Continued.

CHART 6.—October.

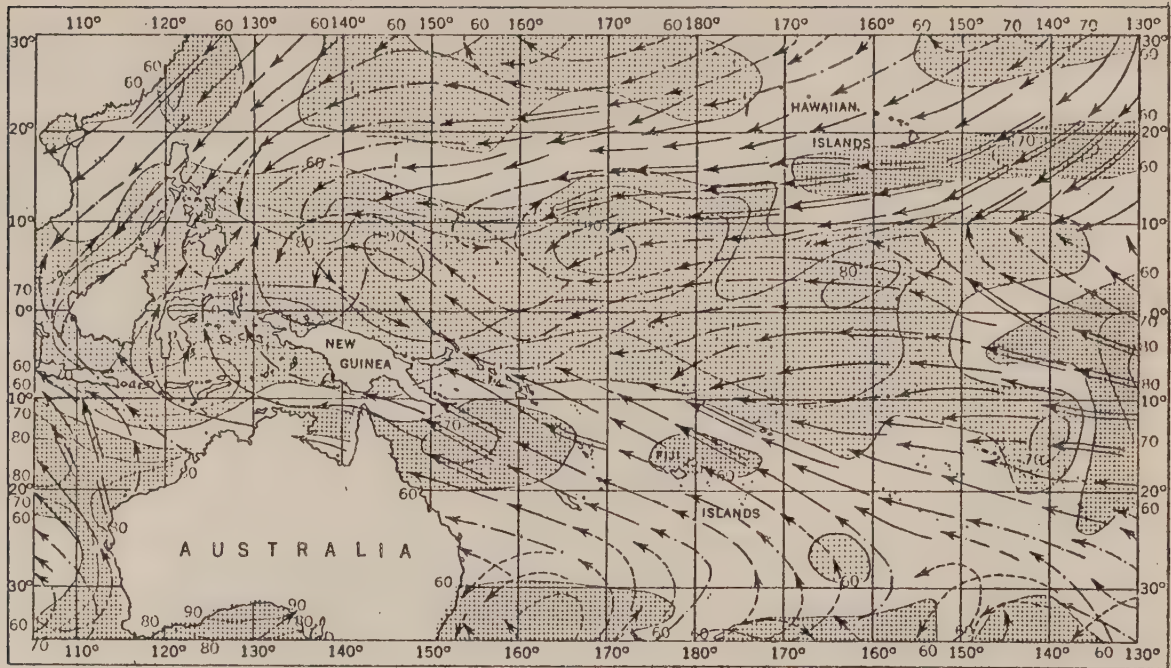


CHART 7.—December.

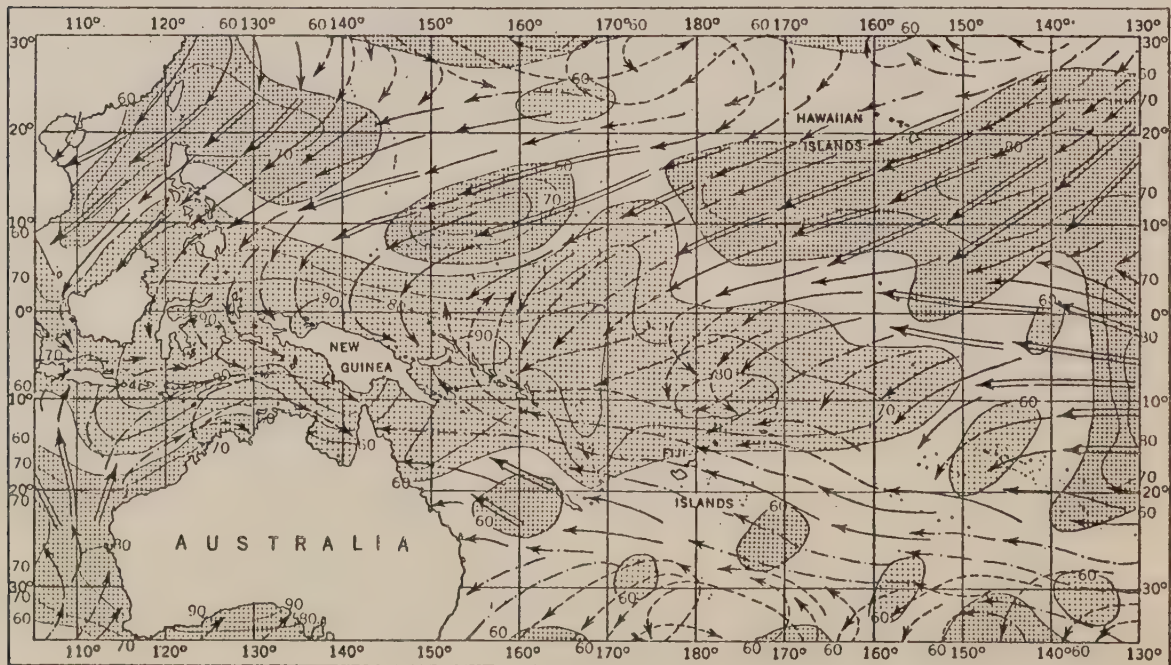


Figure 17.—Continued.

In the Marshalls, the northeast trades predominate in all months particularly in northern waters (U.S. Weather Bureau, 1943). Winds are strong and persistent in November-June in northern waters and from January to June throughout the Marshalls. Weaker trades predominate in the latter half of the year particularly in the southern Marshalls where there is some interposition of southerly to westerly winds.

In lat. 20° to 25° N between long. 140° and 165° E, the trades are less firmly established than they are between lat. 5° and 20° N (U.S. Weather Bureau, 1943). In winter, this area often has north and northwest winds whereas in summer southerly winds--southeast to south--occur frequently at the expense of the northeast winds.

The wind velocities in the western equatorial Pacific between the equator and lat. 5° N at long. 130° to 170° E are rather light with no real significant difference in spread from one season to another (U.S. Weather Bureau, 1943). West of long. 155° E, the mean speed is about 7 knots with frequent calms whereas toward the southeastern Carolines between long. 165° and 170° E, the mean rises to 9 knots with fewer calms. Figure 18 shows the distribution of wind forces in the western Pacific Ocean.

In lat. 5° - 10° N between long. 130° and 175° E, the trades and monsoons blow briskly and the annual velocities rise from about 9 knots in the west to 11 knots in the extreme east (U.S. Weather Bureau, 1943). Here, seasonal differences are more marked; whereas the mean velocities of the summer period are generally between 6 and 9 knots, those of the winter period reach 10 knots or more.

In the more northerly latitudes in 10° - 15° N between long. 130° and 175° E, the annual mean velocities are still higher, reaching 9 to 10 knots in the west and 12 to 13 knots in the east (U.S. Weather Bureau, 1943). In summer, velocities vary between 7 and 10 knots whereas winter velocities are 12 to 15 knots or more.

Approaching the stronger wind circulation projecting seaward from Asia at lat. 15° to 25° N between long. 130° and 170° E, the average velocities reach 11 knots in the west but are somewhat lower in the east, varying between 9 and 10 knots (U.S. Weather Bureau, 1943). West of the Marianas, the mean velocities range between 10 and 15 knots from October to March. At other times of the year, the monthly means are slightly lower, varying between 8 and 11 knots. The summer monsoon, which is very strong toward the Asiatic coast, carries some of its strength a considerable distance seaward in these latitudes. Over the Marianas and further east, both summer and winter winds are lighter.

Although the predominating wind throughout the year in Micronesia is the easterly trade winds, there are certain exceptions and they can best be discussed by examining the data collected at island weather observation stations. Data on monthly mean wind speed and prevailing direction are given for some island stations in Tables 1 to 8.

DISTRIBUTION OF WIND FORCES

Charts 8 to 12.—Explanation

First or upper figures.—Percentage of the total wind observations which record calms is shown to whole numbers in each 5° square.

Second figures.—Percentage of wind observations with Beaufort force 1 to 3, inclusive.

Third figures.—Percentage of wind observations with Beaufort force 4 to 6, inclusive.

Fourth figures.—Percentage of wind observations with Beaufort force 7 and 8.

Fifth or bottom figures.—Percentage with Beaufort force 9 or over.

#Less than 0.5 percent.

*Denotes a square with less than 25 observations available for summarization.

CHART 8.—February.

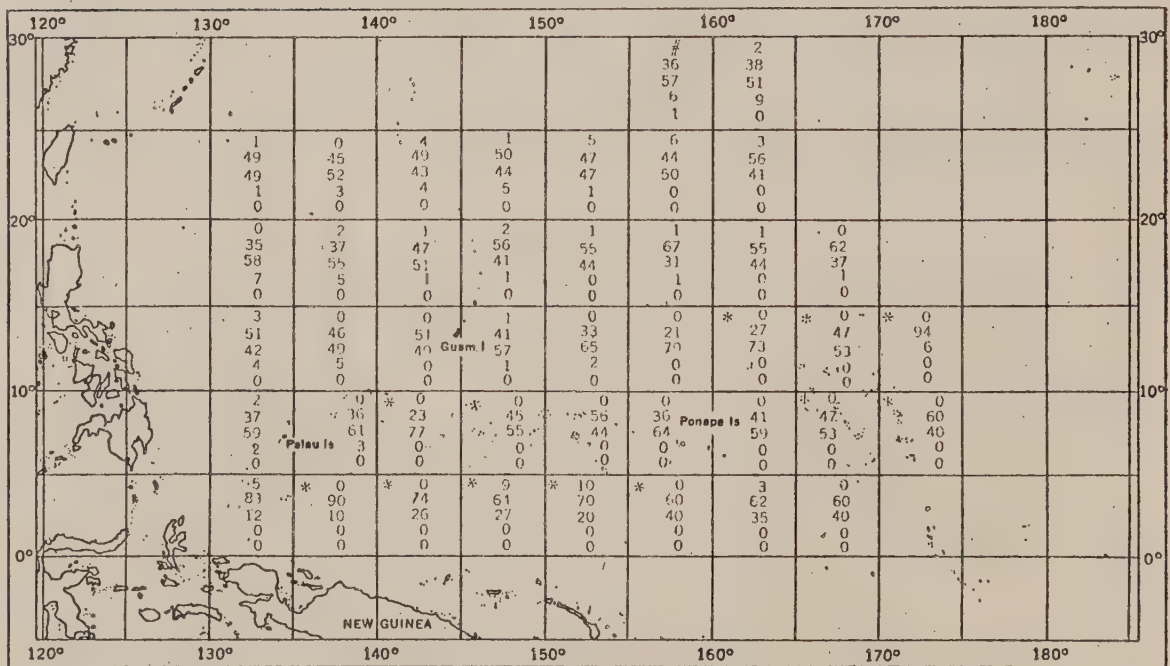


Figure 18.—Distribution of wind forces in the western North Pacific Ocean (U.S. Weather Bureau, 1943).

CHART 9.—May.

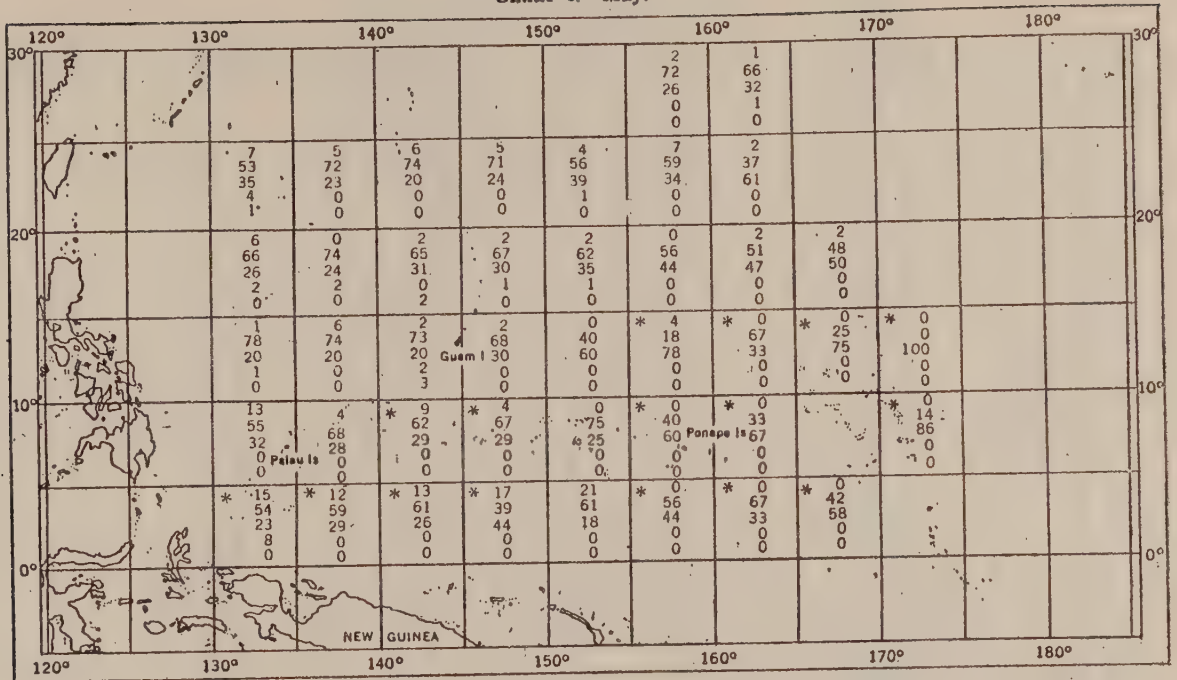


CHART 10.—July.

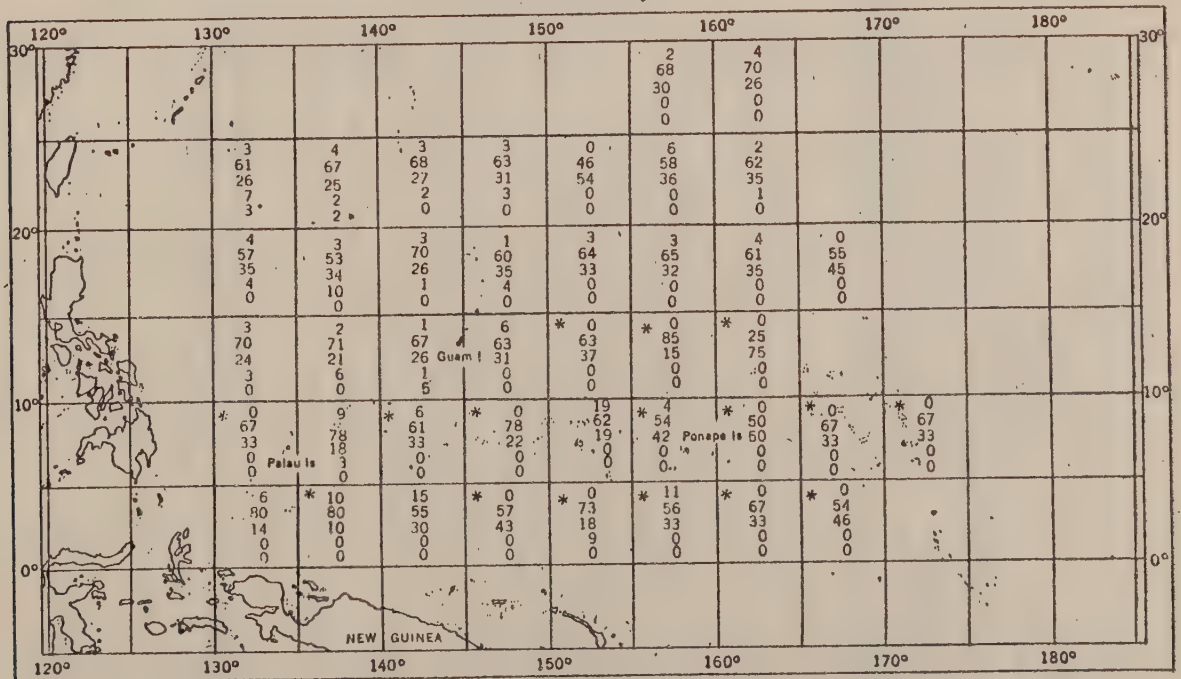


Figure 18.—Continued.

CHART 11.—October.

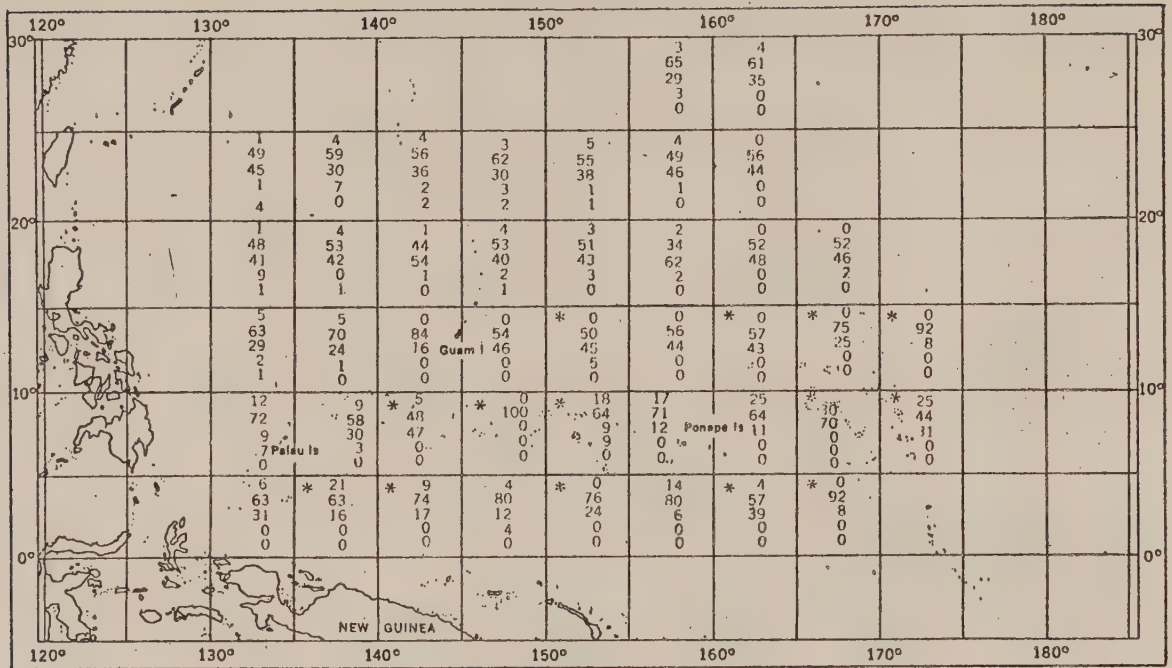


CHART 12.—December.

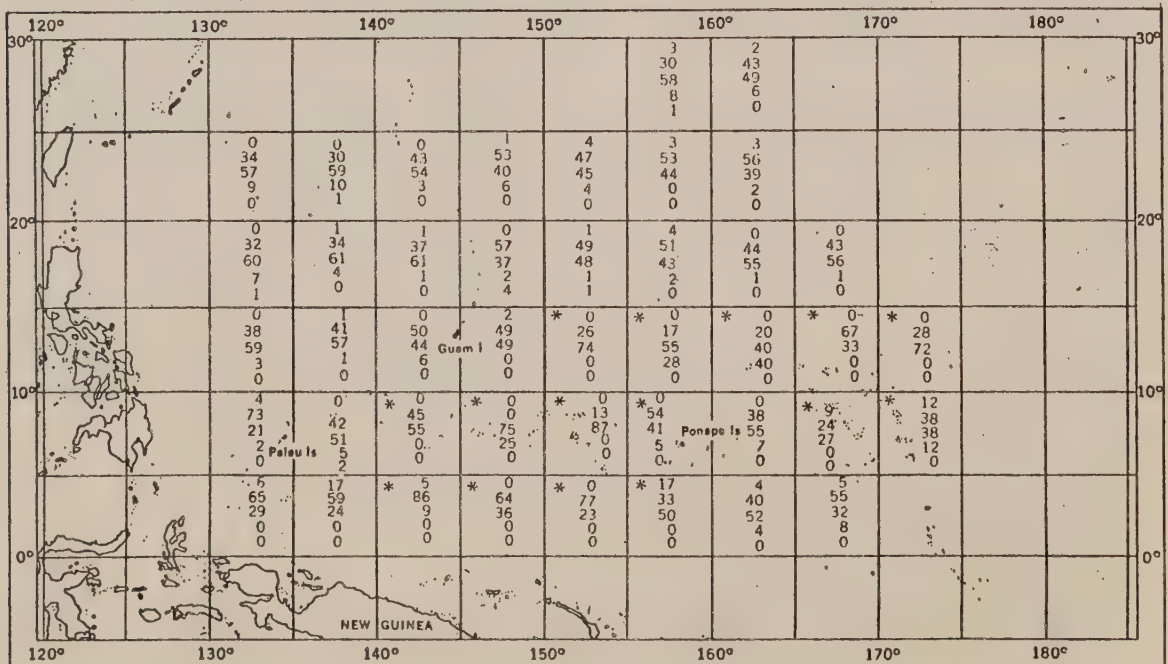


Figure 18.—Continued.

Table 1.--Normals, means, and extremes of meteorological observations at Koror, Palau, Caroline Islands 1941-70 (Environmental Data Service, 1973b).

Month	Temperature				Year	Normal heating degree days (base 65°)				Precipitation				Relative humidity				Wind & direction				Sunshine				Mean number of days				Average daily solar radiation - langbeins																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	Daily maximum	Daily minimum	Record highest	Record lowest		Year	Maximum monthly	Minimum monthly	Year	Maximum in 24 hrs.	Minimum monthly	Year	Maximum in 24 hrs.	Mean total	Mean monthly	Year	Hour	Hour	Hour	Hour	Mean speed	Prevailing direction	Speed	Direction	Year	Pct. of possible sunshine	Clear	Partly cloudy	Cloudy		Precipitation	Snow, ice pellets 1.0 inch or more	Snow, ice pellets 0.1 inch or more	Thunderstorms	Heavy fog	90° and above	32° and below	0° and below																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)	(v)	(w)	(x)	(y)	(z)	(aa)	(ab)	(ac)	(ad)	(ae)	(af)	(ag)	(ah)	(ai)	(aj)	(ak)	(al)	(am)	(an)	(ao)	(ap)	(aq)	(ar)	(as)	(at)	(au)	(av)	(aw)	(ax)	(ay)	(az)	(ba)	(bb)	(bc)	(bd)	(be)	(bf)	(bg)	(bh)	(bi)	(bj)	(bk)	(bl)	(bm)	(bn)	(bo)	(bp)	(bq)	(br)	(bs)	(bt)	(bu)	(bv)	(bw)	(bx)	(by)	(bz)	(ca)	(cb)	(cc)	(cd)	(ce)	(cf)	(cg)	(ch)	(ci)	(cj)	(ck)	(cl)	(cm)	(cn)	(co)	(cp)	(cq)	(cr)	(cs)	(ct)	(cu)	(cv)	(cw)	(cx)	(cy)	(cz)	(da)	(db)	(dc)	(dd)	(de)	(df)	(dg)	(dh)	(di)	(dj)	(dk)	(dl)	(dm)	(dn)	(do)	(dp)	(dq)	(dr)	(ds)	(dt)	(du)	(dv)	(dw)	(dx)	(dy)	(dz)	(ea)	(eb)	(ec)	(ed)	(ee)	(ef)	(eg)	(eh)	(ei)	(ej)	(ek)	(el)	(em)	(en)	(eo)	(ep)	(eq)	(er)	(es)	(et)	(eu)	(ev)	(ew)	(ex)	(ey)	(ez)	(fa)	(fb)	(fc)	(fd)	(fe)	(ff)	(fg)	(fh)	(fi)	(fj)	(fk)	(fl)	(fm)	(fn)	(fo)	(fp)	(fq)	(fr)	(fs)	(ft)	(fu)	(fv)	(fw)	(fx)	(fy)	(fz)	(ga)	(gb)	(gc)	(gd)	(ge)	(gf)	(gg)	(gh)	(gi)	(gj)	(gk)	(gl)	(gm)	(gn)	(go)	(gp)	(gq)	(gr)	(gs)	(gt)	(gu)	(gv)	(gw)	(gx)	(gy)	(gz)	(ha)	(hb)	(hc)	(hd)	(he)	(hf)	(hg)	(hh)	(hi)	(hj)	(hk)	(hl)	(hm)	(hn)	(ho)	(hp)	(hq)	(hr)	(hs)	(ht)	(hu)	(hv)	(hw)	(hx)	(hy)	(hz)	(ia)	(ib)	(ic)	(id)	(ie)	(if)	(ig)	(ih)	(ii)	(ij)	(ik)	(il)	(im)	(in)	(io)	(ip)	(iq)	(ir)	(is)	(it)	(iu)	(iv)	(iw)	(ix)	(iy)	(iz)	(ja)	(jb)	(jc)	(jd)	(je)	(jf)	(jg)	(jh)	(ji)	(jj)	(jk)	(jl)	(jm)	(jn)	(jo)	(jp)	(jq)	(jr)	(js)	(jt)	(ju)	(jv)	(jw)	(jx)	(jy)	(jz)	(ka)	(kb)	(kc)	(kd)	(ke)	(kf)	(kg)	(kh)	(ki)	(kj)	(kk)	(kl)	(km)	(kn)	(ko)	(kp)	(kq)	(kr)	(ks)	(kt)	(ku)	(kv)	(kw)	(kx)	(ky)	(kz)	(la)	(lb)	(lc)	(ld)	(le)	(lf)	(lg)	(lh)	(li)	(lj)	(lk)	(ll)	(lm)	(ln)	(lo)	(lp)	(lq)	(lr)	(ls)	(lt)	(lu)	(lv)	(lw)	(lx)	(ly)	(lz)	(ma)	(mb)	(mc)	(md)	(me)	(mf)	(mg)	(mh)	(mi)	(mj)	(mk)	(ml)	(mn)	(mo)	(mp)	(mq)	(mr)	(ms)	(mt)	(mu)	(mv)	(mw)	(mx)	(my)	(mz)	(na)	(nb)	(nc)	(nd)	(ne)	(nf)	(ng)	(nh)	(ni)	(nj)	(nk)	(nl)	(nm)	(nn)	(no)	(np)	(nq)	(nr)	(ns)	(nt)	(nu)	(nv)	(nw)	(nx)	(ny)	(nz)	(oa)	(ob)	(oc)	(od)	(oe)	(of)	(og)	(oh)	(oi)	(oj)	(ok)	(ol)	(om)	(on)	(oo)	(op)	(oq)	(or)	(os)	(ot)	(ou)	(ov)	(ow)	(ox)	(oy)	(oz)	(pa)	(pb)	(pc)	(pd)	(pe)	(pf)	(pg)	(ph)	(pi)	(pj)	(pk)	(pl)	(pm)	(pn)	(po)	(pp)	(pq)	(pr)	(ps)	(pt)	(pu)	(pv)	(pw)	(px)	(py)	(pz)	(qa)	(qb)	(qc)	(qd)	(qe)	(qf)	(qg)	(qh)	(qi)	(qj)	(qk)	(ql)	(qm)	(qn)	(qo)	(qp)	(qq)	(qr)	(qs)	(qt)	(qu)	(qv)	(qw)	(qx)	(qy)	(qz)	(ra)	(rb)	(rc)	(rd)	(re)	(rf)	(rg)	(rh)	(ri)	(rj)	(rk)	(rl)	(rm)	(rn)	(ro)	(rp)	(rq)	(rr)	(rs)	(rt)	(ru)	(rv)	(rw)	(rx)	(ry)	(rz)	(sa)	(sb)	(sc)	(sd)	(se)	(sf)	(sg)	(sh)	(si)	(sj)	(sk)	(sl)	(sm)	(sn)	(so)	(sp)	(sq)	(sr)	(ss)	(st)	(su)	(sv)	(sw)	(sx)	(sy)	(sz)	(ta)	(tb)	(tc)	(td)	(te)	(tf)	(tg)	(th)	(ti)	(tj)	(tk)	(tl)	(tm)	(tn)	(to)	(tp)	(tq)	(tr)	(ts)	(tt)	(tu)	(tv)	(tw)	(tx)	(ty)	(tz)	(ua)	(ub)	(uc)	(ud)	(ue)	(uf)	(ug)	(uh)	(ui)	(uj)	(uk)	(ul)	(um)	(un)	(uo)	(up)	(uq)	(ur)	(us)	(ut)	(uu)	(uv)	(uw)	(ux)	(uy)	(uz)	(va)	(vb)	(vc)	(vd)	(ve)	(vf)	(vg)	(vh)	(vi)	(vj)	(vk)	(vl)	(vm)	(vn)	(vo)	(vp)	(vq)	(vr)	(vs)	(vt)	(vu)	(vv)	(vw)	(vx)	(vy)	(vz)	(wa)	(wb)	(wc)	(wd)	(we)	(wf)	(wg)	(wh)	(wi)	(wj)	(wk)	(wl)	(wm)	(wn)	(wo)	(wp)	(wq)	(wr)	(ws)	(wt)	(wu)	(wv)	(ww)	(wx)	(wy)	(wz)	(xa)	(xb)	(xc)	(xd)	(xe)	(xf)	(xg)	(xh)	(xi)	(xj)	(xk)	(xl)	(xm)	(xn)	(xo)	(xp)	(xq)	(xr)	(xs)	(xt)	(xu)	(xv)	(xw)	(xx)	(xy)	(xz)	(ya)	(yb)	(yc)	(yd)	(ye)	(yf)	(yg)	(yh)	(yi)	(yj)	(yk)	(yl)	(ym)	(yn)	(yo)	(yp)	(yq)	(yr)	(ys)	(yt)	(yu)	(yv)	(yw)	(yx)	(yy)	(yz)	(za)	(zb)	(zc)	(zd)	(ze)	(zf)	(zg)	(zh)	(zi)	(zj)	(zk)	(zl)	(zm)	(zn)	(zo)	(zp)	(zq)	(zr)	(zs)	(zt)	(zu)	(zv)	(zw)	(zx)	(zy)	(zz)

Partial years data for 1947, 1949 and 1951 considered in extracting extremes of temperature and precipitation above.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Less than one half.
(c) Also on earlier date, month, or year.
(d) Price, an amount too small to be recorded by a minus sign.
(e) Based on data from the station.
(f) Based on data from the station.
(g) Based on data from the station.
(h) Based on data from the station.
(i) Based on data from the station.
(j) Based on data from the station.
(k) Based on data from the station.
(l) Based on data from the station.
(m) Based on data from the station.
(n) Based on data from the station.
(o) Based on data from the station.
(p) Based on data from the station.
(q) Based on data from the station.
(r) Based on data from the station.
(s) Based on data from the station.
(t) Based on data from the station.
(u) Based on data from the station.
(v) Based on data from the station.
(w) Based on data from the station.
(x) Based on data from the station.
(y) Based on data from the station.
(z) Based on data from the station.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement, in miles per hour; and relative humidity in percent. Mean monthly degree days are the sum of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (frozen rain) and frozen snowflakes consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds, or obscuring phenomena to 10 for complete sky cover. Partly cloudy is 3 to 5, mostly cloudy is 6 to 8, and clear is 9 to 10. Cloudy days are 1 to 2, and clear days are 3 to 10.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The Langley denotes one gram calorie per square centimeter.

a Figures instead of letters in a direction column indicate direction in tens of degrees from true North. Letters in a direction column indicate direction in degrees from true North. Letters in a direction column indicate direction in degrees from true North.

† To 8 compass points only.

Table 2.--Normals, means, and extremes of meteorological observations at Yap, Caroline Islands, 1941-70 (Environmental Data Service, 1973f).

Month	Temperature				Normal bearing degree	Precipitation				Relative humidity				Wind				Mean number of days				Average daily solar radiation - Langley's			
	Normal		Extremes			Year	Normal total	Maximum	Minimum	Year	Maximum	Minimum	Year	Maximum	Minimum	Year	Maximum	Minimum	Year	Maximum	Minimum	Year	Maximum	Minimum	
	Day	Month	Record	Year																					Record
Jan	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Feb	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Mar	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Apr	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
May	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Jun	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Jul	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Aug	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Sep	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Oct	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Nov	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0
Dec	55.8	31.2	69.1	1973	0	10.0	2.0	19.2	1.0	8.2	1.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0

a Figures instead of letters in a direction column indicate direction in tens of degrees from true North: 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. Resultant wind is the vector sum of Le., wind directions and speeds divided by the number of observations. If figures appear in the direction column, the corresponding speeds are fastest observed 1-minut values.

To 8 compass points only.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees Fahrenheit; precipitation, including snowfall, is inches; wind movement in miles per hour; and relative humidity in percent. Heating day rate is the sum of positive departures of average daily temperatures from 65° F. Cooling day rate is the sum of negative departures of average daily temperatures from 65° F. Snowfall totals are the sums of positive departures of average daily temperatures from 55° F. Snowfall totals were included in snowfall totals beginning with July 1964. The term "ice pellets" refers to the solid grains of ice (sleet) and particles consisting of snow pellets encased in ice pellets. The term "ice grains" refers to ice grains of ice (sleet) and particles consisting of snow pellets encased in ice grains. Haze for radiation visibility is 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The Langley number is one gram calorie per square centimeter.

(a) Length of record, years, based on January data.
Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological normals (1941-1970).
Less than one-half.
Also on earlier dates, months, or years.
Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
≥ 70° at Alaskan stations.

the prevailing direction for wind in the Normals, means, and Extremes table is from records through 1963.

Table 3.--Normals, means, and extremes of meteorological observations at Truk, Caroline Islands, 1941-70
(Environmental Data Service, 1973e).

Month	Temperature				Normal heating degree days (Base 65°)				Precipitation				Relative humidity				Wind &				Sunshine				Mean number of days				Average daily solar radiation - langley																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
	Normal		Extremes		Normal		Extremes		Normal total		Maximum		Minimum		Maximum		Mean total		Snow, ice pellets		Hour		Hour		Hour		Hour			Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour		Hour	

January - May 1946, August - December 1949, January - April and July - December 1951 data considered in extracting extremes of temperature.
January - May 1946, August - December 1947 and 1949, January - April and July - December 1951 data considered in extracting extremes of precipitation.

(a) Length of record, years, based on January data.
(b) There have been breaks in the record.
(c) Climatological normals (1941-1970).
(d) Also on earlier dates, months, or years.
(e) Trace, an amount too small to measure.
(f) Below zero temperatures are preceded by a minus sign.
(g) The prevailing direction for wind in the Normals, means, and extremes is from recorded through 1963.

Using observations indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree days totals are the sum of negative departures of average daily temperature from 65° F. (from 45° F. first was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calim. Resultant wind is the vector sum of wind directions and speeds. Wind directions are indicated by Roman numerals. The direction column under "fastest mile" the corresponding speeds are based on observed 1-minute values.

§ To 8 compass points only.

Table 4.---Normals, means, and extremes of meteorological observations at Ponape, Caroline Islands, 1941-70
(Environmental Data Service, 1973d).

Temperature				Normal heating degree days (base 65°)				Precipitation				Relative humidity				Wind &				Mean number of days				Average daily solar radiation - langley																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Normal		Extremes		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year		Year</	

(a) Length of record, years, based on January data.
 Other months may be for more or fewer years if there have been breaks in the record.
 (b) Number of years for which data are available.
 (c) Number of years for which data are available.
 (d) Number of years for which data are available.
 (e) Number of years for which data are available.
 (f) Number of years for which data are available.
 (g) Number of years for which data are available.
 (h) Number of years for which data are available.
 (i) Number of years for which data are available.
 (j) Number of years for which data are available.
 (k) Number of years for which data are available.
 (l) Number of years for which data are available.
 (m) Number of years for which data are available.
 (n) Number of years for which data are available.
 (o) Number of years for which data are available.
 (p) Number of years for which data are available.
 (q) Number of years for which data are available.
 (r) Number of years for which data are available.
 (s) Number of years for which data are available.
 (t) Number of years for which data are available.
 (u) Number of years for which data are available.
 (v) Number of years for which data are available.
 (w) Number of years for which data are available.
 (x) Number of years for which data are available.
 (y) Number of years for which data are available.
 (z) Number of years for which data are available.
 (aa) Number of years for which data are available.
 (ab) Number of years for which data are available.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sum of positive departures of average daily temperature from 65° F. Cooling degree day totals are the sum of negative departures of average daily temperature from 65° F. Snowfall is included in snowfall totals beginning with July 1961. "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.
 Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.
 Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

a Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. b Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. c Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. d Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. e Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. f Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. g Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. h Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. i Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. j Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. k Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. l Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. m Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. n Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. o Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. p Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. q Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. r Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. s Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. t Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. u Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. v Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. w Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. x Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. y Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. z Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. aa Figures instead of letters in a direction column indicate direction in tenths of degrees from true North. ab Figures instead of letters in a direction column indicate direction in tenths of degrees from true North.

Table 5.--Normals, means, and extremes of meteorological observations at Majuro, Marshall Islands, 1941-70
(Environmental Data Service, 1973c).

Month	Temperature				Precipitation				Relative humidity				Wind				Sunshine				Mean number of days				Average daily solar radiation - langley's			
	Normal		Extremes		Normal (base 65°)		Year		Snow, ice pellets		Year		Hour		Mean speed		Sunrise to sunset		Pct. of possible sunshine		Sunrise to sunset		Precipitation		Sunrise to sunset		Precipitation	
	Daily		Record		Days (base 65°)		Maximum		Maximum		Maximum		Hour		Direction		Clear		Pct. of possible sunshine		Clear		1.0 inch or more		Clear		1.0 inch or more	
	Maximum	Minimum	Monthly	Record	Year	Record	Year	Year	Year	Year	Year	Year	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour	Hour
J	86.7	77.0	80.8	88	1961*	69	1958	0	8.98	21.97	1961	0.0	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
F	86.1	77.3	80.2	88	1962*	72	1963*	0	9.08	18.34	1957	0.0	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
M	85.3	77.1	81.2	88	1961*	70	1963*	0	9.25	18.51	1955	1.73	1970	8.14	1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A	85.3	76.9	81.1	88	1973*	70	1955	0	10.31	31.10	1971	2.87	1970	6.63	1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M	85.6	77.0	81.3	89	1963	71	1958	0	12.15	22.23	1956	4.93	1967	5.86	1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J	85.4	76.0	81.0	89	1966	70	1958*	0	12.17	16.07	1968	7.34	1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J	85.5	76.6	81.0	89	1969*	72	1973*	0	13.66	18.69	1964	5.34	1961	5.39	1971*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A	85.0	77.0	81.5	91	1969*	71	1955*	0	11.78	16.72	1956	5.33	1959	4.01	1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	86.1	76.7	81.4	91	1969*	72	1959*	0	14.39	21.11	1964	6.83	1963	5.47	1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	86.0	76.6	81.3	91	1958	70	1957*	0	10.00	24.26	1955	7.11	1959	7.19	1955	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	85.6	76.8	81.2	89	1966	72	1973*	0	15.38	22.69	1962	4.33	1972	10.01	1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	85.2	77.0	81.1	88	1968*	70	1958	0	11.88	24.60	1968	2.28	1957	17.68	1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YR	85.4	76.9	81.2	91	1969*	69	1958	0	14.28	31.10	1971	0.40	1970	17.88	1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

March - December 1955 data considered in extracting extremes above.

- (a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
- (b) Climatological normals (1941-1970).
- (c) Data on earlier dates, months, or years.
- (d) Trace, an amount too small to measure.
- (e) Data are preceded by a minus sign.
- (f) Prevailing direction for wind in the Normals.
- (g) Mean, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree days totals are based on the base temperature of 65° F. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 6-7, partly cloudy days 4-7, and cloudy days 8-10 inclusive.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

8 Figures instead of letters in a direction column indicate direction in tens of degrees from true North, i.e., 00 East, 10 South, 20 West, etc. Figures in a direction column indicate direction in minutes of degrees from true North, i.e., 00 East, 10 South, 20 West, etc. Figures in a direction column under "Fusuk mile" the corresponding speeds are faster observed 1-minute values.

9 To 8 compass points only.

Table 6.--Means, totals, extremes, and number of years various meteorological observations were made at Jaluit, Marshall Islands (U.S. Weather Bureau, 1943).

STATION: JALUIT, MARSHALL ISLANDS. POSITION: LATITUDE 5°55' N.,
LONGITUDE 169°38' E. ALTITUDE 20 FEET

Month	Air Temp. °F.					Relative humidity (percent)		Cloud amount (0-10)		Rainfall			1400		Wind												Average number of days with—			
	Mean			Extreme						Ave. amount (inches)	Number of rainy days	Max. 24 hrs. (inches)	Mean velocity (knots) 0700	Mean velocity (knots)	Percentages of observations from—															
	Monthly	Maximum	Minimum	Maximum	Minimum	0700	1400	0700	1400						N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Predominant winds or calm						
																									Fog	Gales	Thunder			
January.....	82	86	77	98	72	85	78	6.6	6.5	10.2	16.7	6.9	13.4	11.5	2	67	18	7	1	1	*	0	4							0.4
February.....	82	87	78	97	72	82	77	5.7	6.4	8.5	13.0	3.2	13.4	11.9	2	59	24	9	2	*	0	0	4							0.8
March.....	83	88	78	95	71	81	77	5.8	6.8	14.2	18.2	6.0	12.9	12.3	*	65	23	8	*	0	0	0	4							1.2
April.....	82	87	78	94	71	83	79	6.8	7.1	15.8	20.4	8.2	11.5	9.6	2	44	34	12	2	1	*	*	5							1.1
May.....	82	87	77	94	71	83	80	6.3	7.1	16.6	23.1	4.1	9.6	8.8	1	39	38	9	2	1	*	1	9							1.4
June.....	82	87	77	93	72	82	79	6.0	6.9	15.3	21.6	6.9	9.6	9.2	1	45	37	7	1	1	1	0	7							1.8
July.....	82	88	77	95	71	82	77	6.6	6.8	15.4	22.1	11.1	6.7	5.6	1	34	32	13	2	1	*	2	15							2.1
August.....	82	88	77	94	71	81	75	6.1	6.5	12.0	19.9	6.0	5.2	4.8	1	31	30	15	3	2	1	1	16							2.1
September.....	82	88	77	95	71	80	75	5.8	6.5	13.1	20.0	4.7	5.2	4.4	1	14	20	29	10	3	1	1	21							1.9
October.....	84	90	77	97	72	80	73	5.9	6.6	12.2	20.2	7.3	6.7	7.0	4	15	26	29	6	4	2	2	12							1.5
November.....	82	88	77	98	70	81	77	6.6	7.0	11.9	19.8	3.7	8.8	8.7	4	36	28	19	3	2	*	1	7							1.6
December.....	82	87	77	98	72	84	78	6.5	7.0	13.6	19.8	7.6	12.3	11.5	3	61	21	8	1	1	*	1	4							0.9
Mean.....	82	88	77	—	—	82	77	6.2	6.8	—	—	—	9.6	8.8	2	42	28	14	3	1	*	1	9	—	—	—	—	—	—	—
Total.....	—	—	—	—	—	—	—	—	—	159	235	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16.7
Extreme.....	—	—	—	98	70	—	—	—	—	—	—	—	11.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Number of years.....	8	8	8	4	4	8	3	5	6	17	11	16	6	6	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	11

Authority: South Sea Bureau
Mitteilungen aus den Deutschen Schutzgebieten Vol. 80, 1917
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International Index

*Less than 0.5 percent

¹Days with .01 inch or more

Table 7.--Means, totals, extremes, and number of years various meteorological observations were made at Ujelang, Marshall Islands (U.S. Weather Bureau, 1943).

STATION: UJELANG, MARSHALL ISLANDS. POSITION: LATITUDE 9°46' N.,
LONGITUDE 160°58' E. ALTITUDE 33 FEET

Month	Air Temp. °F					Relative humidity (percent)		Cloud amount (0-10)		Rainfall			1400		Wind												Average number of						
	Mean			Extreme		0700	1400	0700	1400	Av. amount (inches)	Number of rainy days	Max. 24 hrs. (inches)	Mean velocity (knots) 0700	Mean velocity (knots)	Percentages of observations from—												Predominant winds or calm	days with—					
	Monthly	Maximum	Minimum	Maximum	Minimum										N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Fog	Gales	Thunder							
January.....	81	84	77	90	72	81	77	4.6	4.2	2.1	13	2.4	19.5	19.5	0	50	48	1	0	0	0	0	1					1.5					
February.....	81	85	77	91	72	82	76	4.6	4.0	1.8	13	2.1	19.5	19.1	0	45	54	1	0	0	0	0	0					.5					
March.....	81	86	77	91	73	82	76	4.4	3.9	2.6	12	6.3	18.0	17.5	0	44	53	2	0	0	0	0	1					.0					
April.....	82	86	77	91	73	84	78	4.9	4.8	5.3	17	5.7	16.4	15.4	0	31	62	5	1	1	0	0	0					.0					
May.....	82	87	78	90	73	85	79	5.1	4.7	6.6	19	3.4	13.4	13.4	0	23	68	7	1	1	0	0	0					.0					
June.....	82	87	78	90	73	85	79	5.0	4.8	7.1	21	7.1	12.3	12.4	0	25	67	7	0	0	0	0	1					.3					
July.....	83	88	77	93	72	86	79	5.1	4.9	8.4	23	5.7	10.1	10.5	1	19	61	9	2	2	3	1	2					.0					
August.....	83	88	77	94	71	87	78	4.8	4.8	8.5	22	4.5	7.5	8.8	4	13	44	13	5	7	6	3	5					.0					
September.....	83	88	77	93	73	87	80	5.4	5.3	10.3	24	5.0	8.3	8.8	5	16	34	12	7	9	7	4	6					.0					
October.....	83	88	77	95	73	87	80	5.3	5.3	10.4	23	5.2	9.6	10.1	4	18	44	11	5	6	6	3	3					.0					
November.....	82	87	78	92	73	86	80	5.1	5.0	9.6	22	11.7	13.4	13.4	1	28	55	9	2	2	1	1	1					.0					
December.....	82	86	78	90	72	82	78	4.7	4.4	4.9	19	3.9	19.5	19.5	0	42	56	2	0	0	0	0	0					.0					
Mean.....	82	87	77	—	—	84	78	4.9	4.7	—	—	—	14.0	14.1	1	29	54	7	2	2	2	1	2										
Total.....	—	—	—	—	—	—	—	—	—	77.4	228	—	—	—	—	—	—	—	—	—	—	—	—	—				2.3					
Extreme.....	—	—	—	95	71	—	—	—	—	—	—	11.7	—	—	—	—	—	—	—	—	—	—	—	—									
Number of years.....	4-5					8	4	8	6-7	6-8	16	15	17	16	16	16	15	13-14												4			

Authority: Deutsch Überseische Meteorologische Beobachtungen
Mitteilungen aus den Deutschen Schutzgebieten
Department of Agr. - Reed

Table 8.--Normals, means, and extremes of meteorological observations at Guam, Mariana Islands, 1941-70 (Environmental Data Service, 1973a).

[illegible]

Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.

(b) + + + + +
 There have been increases in the record climatic normals (1961-1970).
 Less than one half.
 Also on earlier dates, months, or years.
 Trace, an amount too small to measure.
 Below zero temperatures are preceded by a minus sign.
 - 90° or Alaskan stations.

Below zero temperatures are produced by winds $> 70^{\circ}$ at Alaskan stations. The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

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Unless otherwise indicated, dimensional units used in this bulletin are temperatures in degrees Fahrenheit, relative humidity in percent, precipitation in inches, F. cooling degree days are the sums of negative average daily temperatures from 63° F. Cooling degree day totals are the sums of positive average daily temperatures from 63° F. The term "pollen count" includes pollen grains beginning with July 1942. The term "pollen pellets" includes solid grains of life (seeds) and particles consisting of some pellets consisting in a thin layer of life. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or cloudiness 0.3, partly cloudy days 4-7, and clear days in based on average cloudiness 8-10, mostly clear 11-12, and clear days 13-10 (mostly).

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The Langley cover, the number of clear days in a month, and the average one gram calorie per square centimeter, average one gram calorie per square centimeter.

Solar radiation data are the averages of direct and diffuse components, measured one gram calorie per square centimeter.

Figures instead of letters in a direction column indicate direction in tens of degrees from true North: 09 = East, 18 = South, 27 = West, 36 = North, and 00 = Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column, the resultant wind direction is the direction of the resultant vector. If figures appear in the speed column, the corresponding speeds are the corresponding speeds are the fastest observed 1-minute values.

† Data through 1964 and January 1970 to date --- data for incomplete years not included.

* To 8 compass points only. For period 1968-1970.

* Data through 1964 with station operating less than 24 hours daily, plus data for January 1970 through June 1971 based on 22 hourly observations per day. Beginning July 1971, data were based on observations at intervals of 3 hours. In 1972, the station operated less than full time with changes in schedule during the year.

At Palau Islands, which are located near the western edge of Micronesia, the northeast trades prevail in December-March (Table 1) ([U.S.] Environmental Data Service (EDS), 1973b). Winds are generally light to moderate at this time. In April, the frequency of northeast winds decreases while the frequency of east winds increases. By May, the predominant winds are from the east with southeast winds just as frequent as northeast ones. In June, the directions most frequently observed are east and southeast (U.S. Weather Bureau, 1943). From July to October, the south to west monsoons are prevalent. Winds are west-southwesterly with the Intertropical Convergence Zone (ITCZ) in the vicinity of Koror at this time (EDS, 1973b). By November, Koror is usually near the heart of the zone and this is reflected in the high frequency of calm periods and of light winds from all directions. Calms are frequent in all months except February-March. Winds are light in January-March, averaging 5.5 knots, and in June with an average of 3 knots.

East of Palau, the ITCZ lies near Yap during the northern summer particularly as it moves northward in July and returns southward in October (Table 2) (EDS, 1973f). The southwest monsoon gradually replaces the northeast trades in July and becomes well established by August (U.S. Weather Bureau, 1943). At this time, there are frequent periods of calm and light variable winds; however, heavy shifting winds can also occur particularly during periods of heavy showers or thunderstorms. The northeasterly wind gradually replaces the southwest monsoon in September-October. From November through June, Yap is under the influence of the northeast trade winds.

In the vicinity of Truk, the climate is primarily influenced by the northeasterlies from about November to June (Table 3) (EDS, 1973e). In April, however, the trades are beginning to diminish in strength and by July, Truk is influenced by lighter and more variable winds of the doldrums. In July-October, the island frequently comes under the influence of the ITCZ, which has moved northward into this vicinity. Also during this period, moist southerly winds are most frequent and humidity is often oppressively high.

The trade wind regime is unsteady at Ponape, resulting in frequent calms particularly in April-December (U.S. Weather Bureau, 1943). In January-March the wind velocity averages 7 knots but in July-October the wind speed diminishes to 3 knots during the monsoon (Table 4) (EDS, 1973d). Northeast to east trades prevail from December to April but in May-June southerly winds increasingly interrupt the trade winds. July-October winds are from the southwest but by November the trades gradually return and predominate.

At Majuro, the trade winds prevail throughout the year (EDS, 1973c). As in Truk and Ponape, Majuro comes under the influence of the ITCZ as it moves across the area during the summer and the trade winds are frequently interrupted (Table 5).

At Jaluit in the southern Marshalls, the trades from northeast to east strongly predominate from about December to June (Table 6) (U.S. Weather Bureau, 1943). During the remainder of the year, although the northeast to east trades continue to predominate, there are frequent periods of southeasterly and southerly winds. In June-December, winds are very light, averaging 1 to 3 knots, but in other months they vary between 5 and 8 knots.

In the northern Marshalls at Ujelang, wind velocity is higher than at Jaluit (U.S. Weather Bureau, 1943). In winter, the winds average 19 knots but gradually decrease to 8 or 9 knots by August-September (Table 7). The prevalent wind is from the east and northeast. Southeast to westerly winds interrupt the trades about half of the time in August-October.

At Guam in the Marianas, wind conditions vary markedly and define the seasons (EDS, 1973a). In winter, the dominant winds are easterly and east-northeasterly (Table 8). Although 70% of the annual winds are from the northeast to east, this figure may rise to 90% in December-April (U.S. Weather Bureau, 1943). In July-October, the trades, blowing out of the east, are often interrupted by southeast to southwest winds. The trades are most constant during the dry months of January-April (EDS, 1973a). During the wet season from mid-July to mid-November, there is often a weakening of the trades. And because Guam is situated near the dividing line of the Asiatic summer monsoon and the northeast trades, the prevailing wind direction in August-September is southwesterly in some years and northeasterly in others (U.S. Weather Bureau, 1943). Monthly wind velocity averages 3 to 7 knots with winter winds strongest. Variable winds are light.

RAINFALL

The atmosphere over the tropical oceans is saturated with moisture at all times, and any significant decrease in temperature to which the air masses are subjected will cause rain (Wiens, 1962). Islands with high and wide surfaces fronting the prevailing winds are likely to have more rainfall on the windward side, while on the leeward side moisture deficiency may occur. This windward-leeward difference in rainfall is reflected in differences in vegetation. Thus, it is difficult to describe patterns of average annual rainfall among the high volcanic Pacific islands.

Generally, the high average annual rainfalls are those occurring in tropical areas where differences in vertical temperature are largest (Wiens, 1962). The volume of air uplifted to bring about rain increases with the velocity of the wind carrying the moisture. There

are large geographical differences in the potential for precipitation because some parts of the Pacific have higher average wind velocities than others. Therefore, the western tropical Pacific is likely to have higher rainfall because of the higher frequency of typhoon occurrences. Figure 19 shows the frequency of rain or showers, thunderstorms, and squalls over the western Pacific Ocean.

Rainfall varies not only among areas in the Pacific but also among years (Wiens, 1962). The ITCZ is an area in which large-scale rising air masses bring comparatively large volumes of rain regardless of orography. However, this zone must not be looked upon as a fixed area which invariably gets high rainfall. Great fluctuations in annual rainfall are recorded on some of the low-lying atolls in the tropical Pacific. For example, Fanning Island, not far from the equator, recorded 208 in. (528 cm) of rainfall in 1905 but received only 28 in. (71 cm) in 1950.

In Micronesia, drizzle, the least common of all the types of sea rainfall, occurs occasionally in low latitudes (U.S. Weather Bureau, 1943). In higher latitudes, it is more frequent and is observed in 1%-2% of the monthly observations.

Rain and showers in Micronesia occur more frequently and they represent 15%-20% or more of the annual observations made between the equator and lat. 10°N (U.S. Weather Bureau, 1943). Based on island observations in the Caroline and Marshall groups, this latitudinal belt has the heaviest and most frequent rainfall. Ships' observations also showed that the area bounded by the equator and lat. 5°N between long. 140° and 145°E is the wettest locality. Seasonal differences in rainfall are not clearly discernible over the vast oceanic extent near the equator and this is reflected on the islands within this belt where wet or dry seasons are not as sharply differentiated as they are farther north.

This belt of heavy annual rainfall of 100 in. (254 cm) or more stretches from Palau through the other islands of the Caroline group to the southern Marshalls (U.S. Weather Bureau, 1943). Narrowing somewhat toward the Marshalls, this rainfall belt marks the ITCZ, the meeting zone of the North and South Pacific trade winds in the east and the easterly and westerly monsoons in the west. Orographic influences on rainfall are entirely lacking on islands that are low and small but are distinctly perceptible on high islands.

Rainfall in the Caroline Islands is shown by meteorological data collected at Palau, Yap, Truk, Ponape, and Kusaie. Palau is an example of high volcanic islands with orographic influences on rainfall. At Koror, Palau, precipitation is heavy with an average of 144 in. (366 cm) per year in 1941-70 and 150 in. (381 cm) or more in a year is not

FREQUENCY OF RAIN AND SHOWERS—THUNDERSTORMS AND SQUALLS

Charts 18 to 22.—Explanation

First or upper figures.—Percentage of rain and showers.

Second or middle figures.—Percentage of thunderstorms.

Third or lower figures.—Percentage of squalls.

*Denotes a square with less than 25 observations available for summarization.

The values given are percentages, in whole numbers and tenths, of observations (1879-1933) which recorded these elements.

For example.—In February in the square 5° N. to 10° N. and 130° E. to 135° E., 25.6 percent of all observations showed rain and showers, 4.6 percent recorded thunderstorms, and 11.6 percent recorded squalls.

CHART 18.—February.

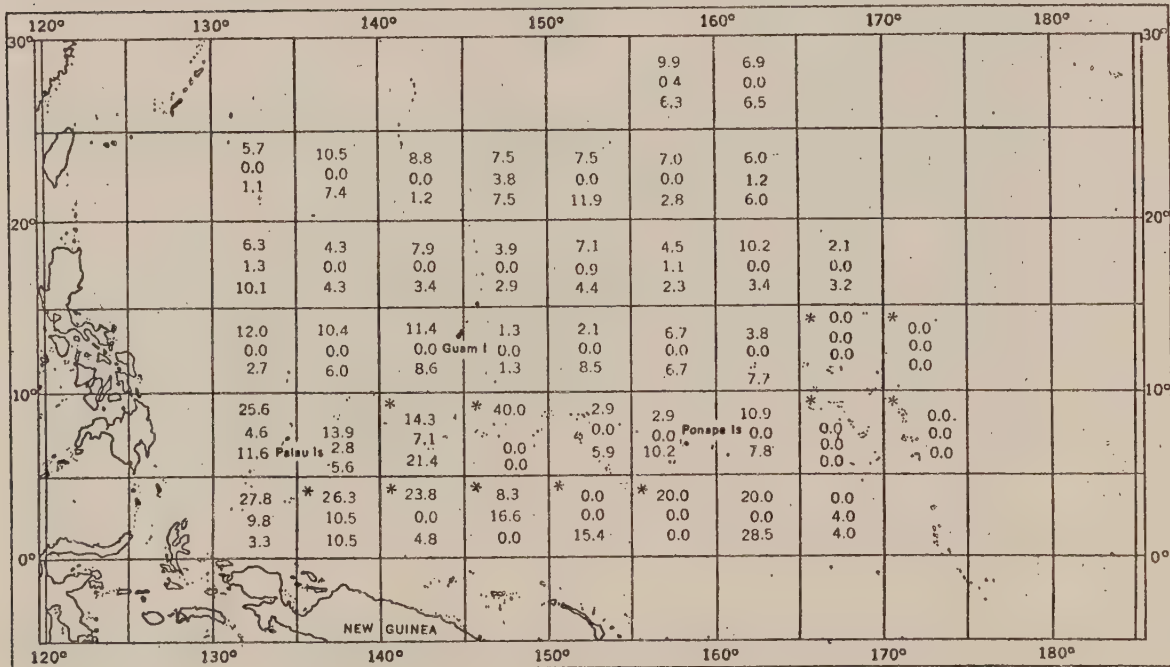


Figure 19.—Frequency of rain and showers, thunderstorms, and squalls in the western North Pacific Ocean in February (U.S. Weather Bureau, 1943).

CHART 19—May.

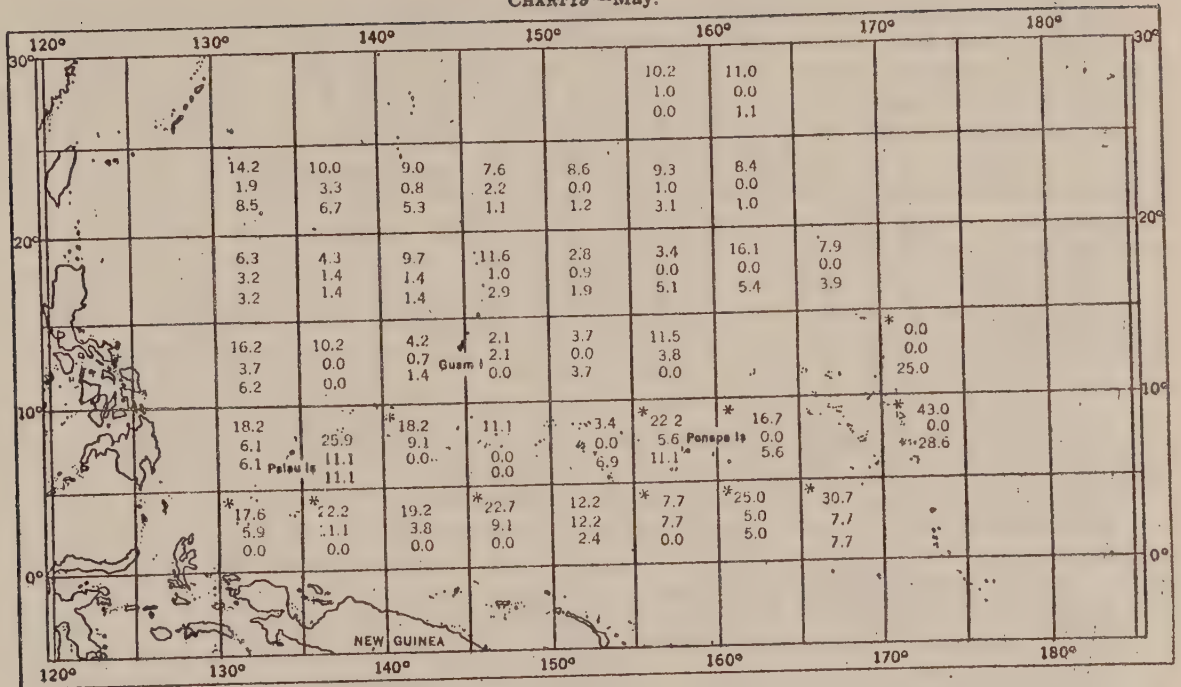


CHART 20—July.

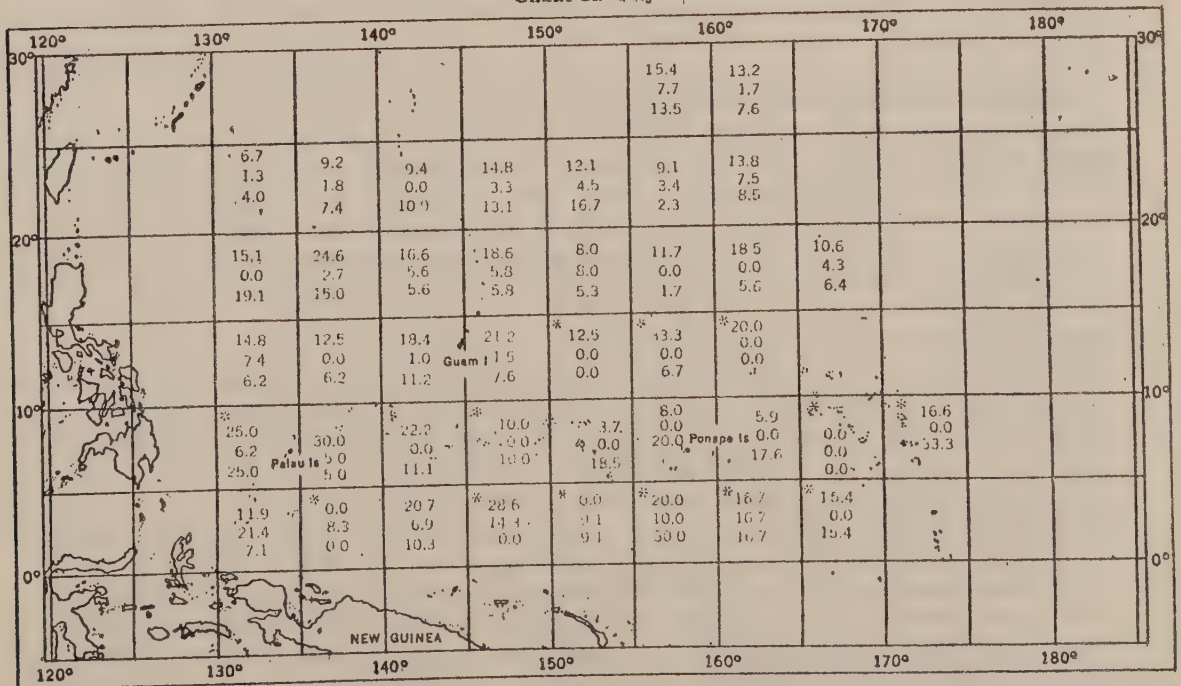


Figure 19.—Continued.

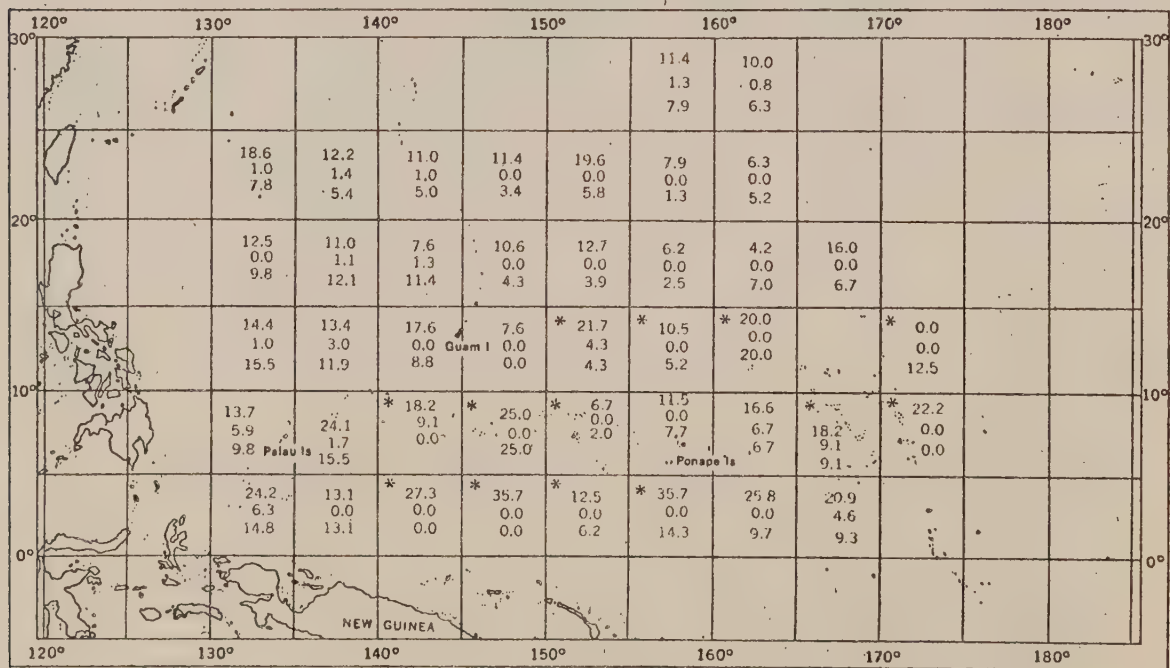
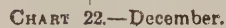


Figure 19.--Continued.

unusual (Table 1) (EDS, 1973b). Monthly rainfall is highly variable from year to year with monthly differences sometimes as much as 15-20 in. (38-51 cm). In all months except February, March, and April (Figure 20), which are the driest months of the year, normal precipitation exceeds 10 in. (25 cm). Rainfall, heaviest in December-January, decreases sharply when the ITCZ moves well south of the islands. Usually, sometime in June, the ITCZ moves northward across Koror, bringing with it heavy rainfall and thunderstorms. During this period, there may be as much as an inch (3 cm) of rain in 15-30 min. Because the ITCZ usually remains slightly north of Koror from July to October, heavy rainfall persists. The convergence zone is almost directly over Koror in November and this is reflected in the high frequency of calms and light winds and continued heavy rain.

Yap, which is 2° north of the 0°-10° latitudinal belt of heavy rainfall, is within the sweep of westerly summer monsoons (U.S. Weather Bureau, 1943). During the northern summer, the ITCZ lies near Yap as it moves northward and southward from July to October (EDS, 1973f). At this time, showers, interspersed with heavier showers and thunderstorms predominate. In 1941-70, the mean annual rainfall was 122 in. (310 cm). According to Table 2 and Figure 20, February-April are the driest months. In other months, normal rainfall exceeds 8 in. (20 cm), with July being the wettest. Cloudless days are rare at Yap. From May through December, a common daily occurrence is to have the morning's fair-weather clouds build up into towering cumulus by late afternoon followed by evening and early morning showers. In such showers visibility may be less than 5 mi (9 km).

Lamotrek atoll, which is in the Yap District but geographically located between the Yap and Truk groups, has an average annual rainfall of 104 in. (264 cm) (U.S. Weather Bureau, 1943). Table 9 and Figure 20 show that summer is the wettest period with the highest monthly rainfall of over 13 in. (33 cm) occurring in August. Late winter and early spring are the dry season with February usually the driest month of the year with an average rainfall of 6 in. (15 cm).

In 1941-70, rainfall at Truk averaged 146 in. (371 cm) annually (Table 3) (EDS, 1973e). At Truk, the relatively dry period from January to March, when monthly rainfall averages 8 in. (20 cm) or less, is the most pleasant time of the year (Figure 20). February is the driest month with an average of only 6 in. (15 cm) and 17-19 days of measurable rain. In April-December, monthly averages vary between 12 and 16 in. (30 and 41 cm) with 21-25 rainy days per month. Rainfall varies widely from month to month as well as from year to year in amount and in seasonal distribution. Even in the dry season from January to March, monthly rainfall has been as much as 24 in. (61 cm) in some years; however, dry spells are not uncommon, and rainfall has been observed to be less than an inch (3 cm) at this time of the year. Annually, rainfall at Truk has been as low as 120 in. (305 cm) and as high as 180 in. (457 cm).

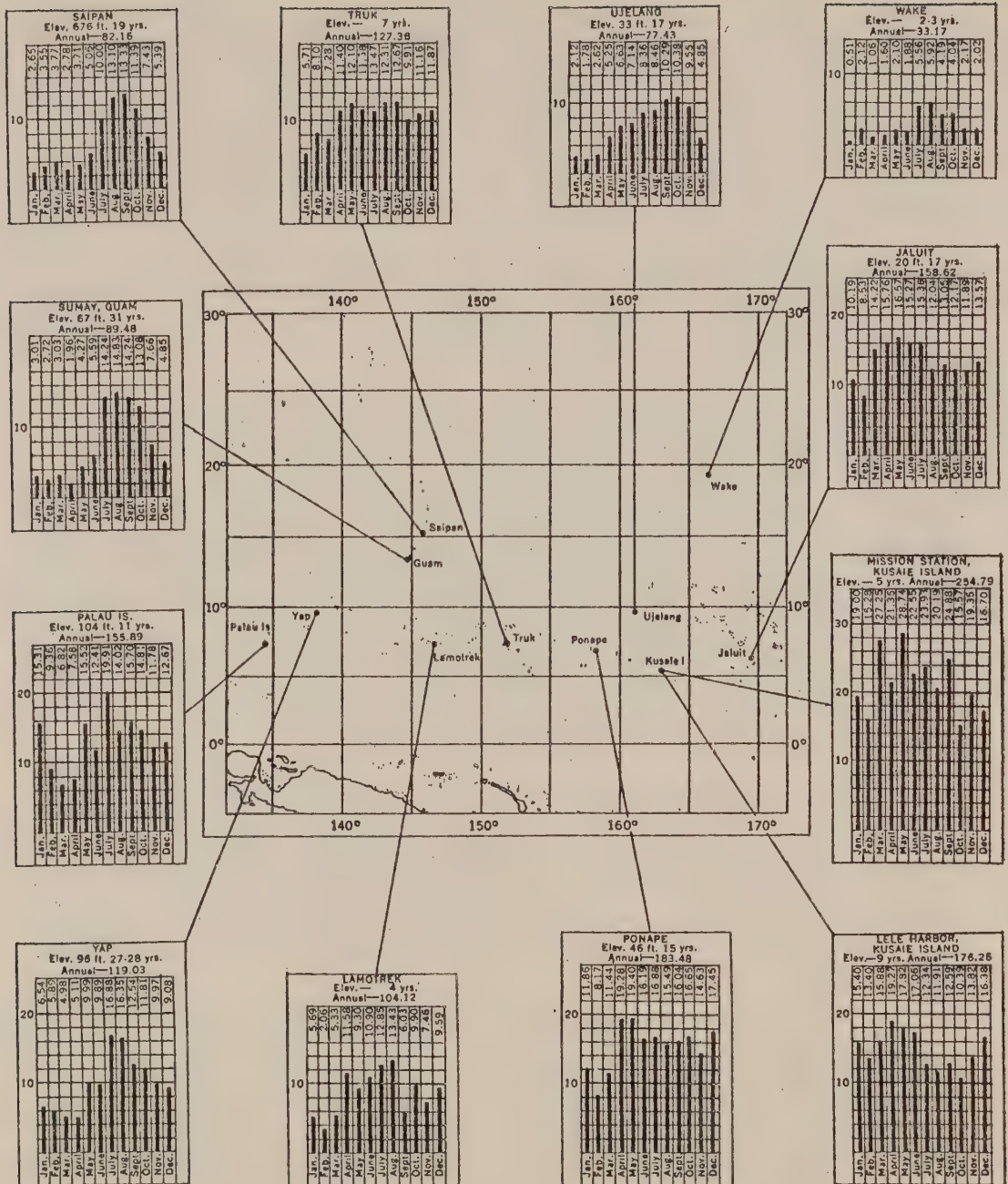


Figure 20.--Seasonal distribution of rainfall. The rainfall profiles shown are based on average monthly rainfall recorded in inches (U.S. Weather Bureau, 1943).

Table 9.--Monthly means, totals, extremes, and number of years rainfall observations were made at Lamotrek, Caroline Islands (U.S. Weather Bureau, 1943).

STATION: LAMOTREK, CAROLINE ISLANDS. POSITION: LATITUDE 7°27' N.,
LONGITUDE 146°24' E.

Month	Air Temp. °F					Relative humidity (percent)	Cloud amount (0-10)	Rainfall			Wind											Predominant winds or calm	Average number of days with—				
	Mean		Extreme					Av. amount (inches)	Number of rainy days 1	Max. 24 hrs. (inches)	Mean velocity (knots)	Maximum velocity (knots)	Percentages of observations from—														
	Monthly	Maximum	Minimum	Maximum	Minimum								N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm		Fog	Gales	Thunder		
January.....								5.7	13	1.9																	
February.....								2.1	6	1.6																	
March.....								5.3	8	2.9																	
April.....								11.6	8	4.7																	
May.....								9.3	13	3.2																	
June.....								10.9	18	3.0																	
July.....								12.9	18	2.5																	
August.....								13.4	16	3.6																	
September.....								6.0	14	3.2																	
October.....								9.9	10	2.2																	
November.....								7.5	12	4.1																	
December.....								9.6	12	6.1																	
Mean.....																											
Total.....								104	148																		
Extreme.....										6.1																	
Number of years.....								4	4	4																	

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¹Days with .01 inch or more

At Ponape, rainfall is heavy and frequent throughout the year, with an annual average of 194 in.(493 cm) in 1941-70 (Table 4) (EDS, 1973d). April and May are the wettest with an average of more than 19 in.(48 cm) per month (Figure 20). Rainfall is high even during the driest period--January-March--with averages of nearly 12 in.(30 cm) in each month. The result is that measurable rain is observed on about 300 days a year. Orographic rainfall due to moist air rising over the steep and rugged terrain of the island adds to the total rainfall received during the trade wind season as well as when the area comes under the influence of the ITCZ.

Orographic influence on rainfall is also well demonstrated at Kusaie in the extreme southeastern Carolines (Tables 10 and 11). Data from U.S. Weather Bureau (1943) show that at Mission Station on the west coast of the island, the mean annual rainfall was 255 in.(648 cm) with over 20 in.(51 cm) falling monthly from March to September (Figure 20). In drier months, the monthly rainfall varied between 15 and 19 in.(38 and 48 cm). Mountains separate the west from the east coast where at Lele Harbor rainfall averaged 176 in.(447 cm). Monthly rainfall here varied between 19 in.(48 cm) in April and 10 in.(25 cm) in October. The wet seasons at Kusaie are in December and in March-June; dry periods are in late summer to autumn and in February.

In the Marshalls, rainfall is shown by meteorological data collected at Ujelang, Jaluit, and Majuro.

Ujelang, located in a zone where the northeast trades are more settled and prevalent, has a mean annual rainfall of 77 in.(196 cm) (U.S. Weather Bureau, 1943). Table 7 and Figure 20 show that the dry season is in January-March with minimum rainfall usually in February. In February-March, drought conditions have resulted in some years because total rainfall was extremely low, varying between 0.3 and 0.4 in.(0.8 and 1.0 cm). There is a gradual increase in rainfall from April culminating in September-October when the mean rainfall is greater than 10 in.(25 cm) in each month.

Unlike Ujelang, which is a zone of strong prevailing northeast trades, Jaluit is located in an area where the interchange of northerly and southerly trade winds is relatively strong (U.S. Weather Bureau, 1943). The result is that Jaluit has a mean rainfall of 159 in.(404 cm) per year or more than twice the mean at Ujelang. The height of the rainy season is in March-July, but Table 6 and Figure 20 show that average rainfall of 10 in.(25 cm) or more occurs in all months except February. The wettest month of May has an average rainfall of 17 in.(43 cm) but the amounts over the years have been extreme, varying from 8 in.(20 cm) to 36 in.(91 cm). Even February, the driest month, has had extremes of 2 in.(5 cm) and 16 in.(41 cm).

Table 10.--Monthly means, totals, extremes, and number of years rainfall observations were made at Kusaie, Mission Station, Caroline Islands (U.S. Weather Bureau, 1943).

STATION: KUSAIE, MISSION STATION, CAROLINE ISLANDS. POSITION: LATITUDE 5°19' N., LONGITUDE 162°59' E.

Month	Air Temp. °F.					Relative humidity (percent)	Cloud amount (0-10)	Rainfall			Wind											Predominant winds or calm	Average number of days with—				
	Mean		Extreme					Av. amount (inches)	Number of rainy days ¹	Max. 24 hrs. (inches)	Mean velocity (knots)	Maximum velocity (knots)	Percentages of observations from—														
	Monthly	Maximum	Minimum	Maximum	Minimum								N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm		Fog	Gales	Thunder		
January.....								19.0	21	3.3																	
February.....								15.3	20	4.9																	
March.....								27.3	26	5.4																	
April.....								21.4	25	3.0																	
May.....								28.7	27	4.9																	
June.....								22.6	25	3.9																	
July.....								23.9	28	4.1																	
August.....								20.2	23	6.8																	
September...								24.9	21	10.4																	
October.....								15.6	20	4.5																	
November.....								19.4	21	8.4																	
December.....								16.7	20	3.3																	
Mean.....																											
Total.....								255	280																		
Extreme.....										10.4																	
Number of years.....								10	10	10																	

Authority: Mitteilungen aus den Deutschen Schutzgebieten
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¹Days with .01 inch or more

Table 11.--Monthly means, totals, extremes, and number of years rainfall observations were made at Kusaie, Lele Harbor, Caroline Islands (U.S. Weather Bureau, 1943).

STATION: KUSAIE, (LELE HARBOR) CAROLINE ISLANDS. POSITION: LATITUDE 5°20' N., LONGITUDE 163°01' E.

Month	Air Temp. °F					Relative humidity (percent)		Cloud amount (0-10)		Rainfall			Wind												Average number of days with—																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	Mean		Extreme							A.v. amount (inches)	Number of rainy days	1 Max., 24 hrs. (inches)	Mean velocity (knots)	Maximum velocity (knots)	Percentages of observations from—																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	Monthly	Maximum	Minimum	Maximum	Minimum	N.	NE.	E.	SE.						S.	SW.	W.	NW.	Calm	Predominant winds or calm	Fog	Gales	Thunder																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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¹Days with .01 inch or more

At Majuro, located roughly 110 mi (204 km) northeast of Jaluit, rainfall is also heavy with monthly averages of 10 in. (25 cm) or more in most months (EDS, 1973c). Table 5 shows that January-March are relatively drier than April-December when the rainfall averages are 10 in. (25 cm) more each month. The height of the wet season is in October-November when the island usually receives over 15 in. (38 cm) of rain each month.

Northward of the 0°-10° latitudinal belt, between 10° and 15°N, rainfall lessens, but 10%-15% of the ships' reports show continued rain and showers (U.S. Weather Bureau, 1943). Between lat. 15° and 20°N, rain and showers were reported in 10%-12% of the observations. The annual frequency of rain and showers between lat. 20° and 30°N decreased further to 8%-10% of the observations. Seasonal differences in rainfall within these various latitudinal belts are not sufficiently pronounced at sea to warrant special attention.

Meteorological data were available from two island stations--Guam and Saipan--in the Marianas.

At Guam, although temperature and humidity vary only slightly throughout the year, rainfall and wind conditions vary markedly (EDS, 1973a). The variations in the latter two weather elements define the two primary and two secondary seasons on Guam. The dry season, which extends from January through April, and the wet season, which extends from mid-July to mid-November are the primary ones (Table 8 and Figure 20). The secondary seasons are transitional ones, which may be either rainy or dry depending on the nature of the particular year. These are from May to mid-July and mid-November to December. Table 8 shows that the mean annual rainfall on Guam is 91 in. (231 cm). On the windward or east side of the higher mountains, the mean annual average is about 95 in. (241 cm), whereas along the western coast of the southern half of Guam, the rainfall is lower averaging 80 in. (203 cm). Usually, rainfall in the dry season accounts for about 15% of the annual total whereas that in the wet seasons contributes 55%.

Saipan, some 2° north of Guam and dominated by its high peaks, has a mean annual rainfall of 82 in. (208 cm) (U.S. Weather Bureau, 1943). Table 12 and Figure 20 show that the rainy season on Saipan is in July-October when monthly averages vary between 10 and 13 in. (25 and 33 cm). The dry season, which has rainfall averaging 3 to 4 in. (8 to 10 cm) monthly, is in January-May. The greatest monthly rainfall on record at Saipan, reaching 25 in. (64 cm), occurred in October. The lowest October amount was 4 in. (10 cm).

Table 12.--Monthly means, totals, extremes, and number of years various meteorological observations were made at Saipan Island (Garapan), Marianas group (U.S. Weather Bureau, 1943).

STATION: SAIPAN ISLAND (GARAPAN) MARIANAS GROUP. POSITION: LATITUDE 15°14' N.,
LONGITUDE 145°46' E. ALTITUDE 676 FEET

Month	Air Temp. °F.					Relative humidity (percent)		Cloud amount (0-10)		Rainfall			Wind											Average number of					
	Mean			Extrame		0600	1400	0600	1400	A.v. amount (inches)	Number of rainy days 1	Max. 24 hrs. (inches)	Mean velocity (knots)	Maximum velocity (knots)	Percentages of observations from—											Predominant winds or calm	days with—		
	Monthly	Maximum	Minimum	Maximum	Minimum										N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Fog	Gales 2		Thunder		
January.....	76	80	72	84	68	85	73	7.2	7.8	2.7	12.4	1.4	5.3													0	1.8	0.1	
February.....	76	80	72	85	69	84	70	7.1	7.4	3.6	11.3	2.1	4.6													0	1.3	0.0	
March.....	77	82	72	85	68	87	71	6.3	7.1	3.8	12.8	6.1	4.9													0	2.2	0.2	
April.....	78	83	73	86	71	87	69	6.6	6.1	2.8	13.6	2.8	4.8													0	1.7	0.4	
May.....	79	84	75	87	69	89	72	6.6	7.2	3.7	12.9	5.3	5.4													0	2.7	0.7	
June.....	80	84	75	87	71	88	71	6.7	6.8	5.1	16.7	3.7	4.5													0	1.7	1.1	
July.....	79	84	75	88	71	91	78	8.5	8.3	10.0	23.5	8.2	4.5													0	5.7	3.7	
August.....	79	84	75	87	69	91	77	8.3	8.6	13.1	22.6	8.9	3.7													0	2.0	2.6	
September.....	79	84	75	89	71	91	79	8.1	8.6	13.3	21.9	5.4	3.7													0	3.5	3.9	
October.....	79	84	75	87	71	91	79	7.4	7.7	11.4	21.8	6.1	4.5													0	4.0	2.8	
November.....	79	83	75	85	72	89	78	7.1	7.3	7.4	19.3	13.1	5.4													0	4.2	1.4	
December.....	78	82	74	84	70	86	75	6.4	7.0	5.4	19.0	3.0	5.5													0	3.2	0.5	
Mean.....	78	83	74	—	—	88	74	7.2	7.5	—	—	—	4.7																
Total.....										82.2	208																0	34.0	17.4
Extreme.....				89	68							13.1																	
Number of years.....	6	6	6	6	6	6	6	6	6	19	13	19	6														6	6	6

Authority: Mitteilungen aus den Deutschen Schutzgebieten, Banden
Meteorological obs. in Japan

¹Days with .01 inch or more

²Winds of 22.4 M.P.H. or more

TROPICAL STORMS

In tropical seas, thunderstorms are more likely to occur at night than during daytime (U.S. Weather Bureau, 1943). On large islands that promote well-developed daytime convection, thunderstorms are likely to form also in the afternoon but these islands are still subject to thunderstorms that move in at night from the sea.

By far the greatest threat to fishing activities at sea in the western Pacific is tropical cyclones or typhoons. According to the U.S. Weather Bureau (1943), the greatest number of tropical cyclones of the western North Pacific originate in or pass through some parts of the area bounded by the equator and lat. 30°N and between long. 130° and 170°E (Figure 21). A few originate in the China Sea or north of lat. 30°N .

Most of the typhoons in this region are first observed between lat. 7° or 8°N and 20°N from long. 125° to 155°E (U.S. Weather Bureau, 1943). The Marshalls and extreme Eastern Carolines are far less likely to experience the effects of typhoons than the Western Carolines and the Marianas. South of lat. 7°N , typhoons are rare. Table 13 shows the total and average monthly and annual numbers of typhoons in 1901-40 in the western North Pacific. The annual numbers can vary considerably.

The movements of typhoons are varied but generally there are three main divisions (U.S. Weather Bureau, 1943). These are storms that move west to northwest toward the Philippines, those that move west or north toward the China coast or southern Japan, and those that remain at sea and finally pass north to northeast toward the seaward side of Japan (Figure 22). For storms that originate west of long. 150° - 160°E , the primary direction is west to northwest.

Typhoons advance at an average rate of 6-12 knots especially on their early westward course (U.S. Weather Bureau, 1943). They may reach speeds of up to 20 knots. At the point of recurve, a typhoon usually slows down and if the bend in the track is sharp, the speed may be imperceptible for a day or two. When moving freely again in a northeasterly direction, the typhoon may have speeds exceeding 25-30 knots.

The advancing speed of typhoons should not be confused with wind velocity, which is related to the steepness of the pressure gradient between the inner and outer parts of the typhoon (U.S. Weather Bureau, 1943). If the gradient is flat, the winds may not be very strong, but if the difference is large, winds of 65 knots may be expected. Actual velocities of 100 knots have been recorded on land instruments.

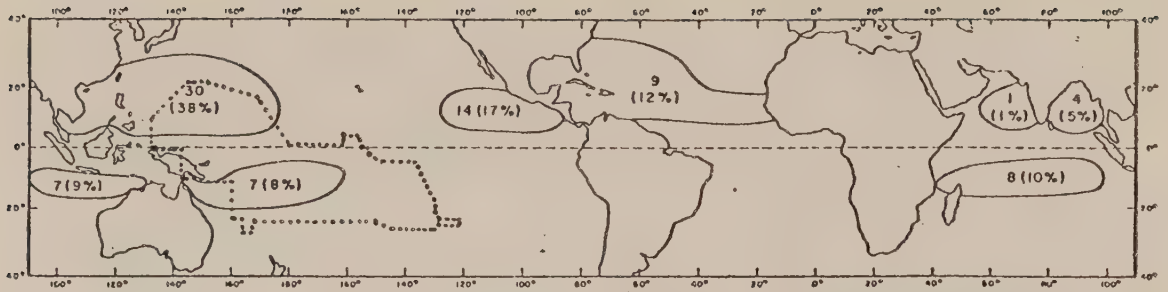


Figure 21.--Average annual number (and percent of global total) of tropical cyclones of significant intensity in each development area. South Pacific Commission Area including Micronesia is shown by dotted line (adapted from Atkinson, 1971 by Hickman, 1973).

Table 13.--The total and average number of typhoons observed in the western North Pacific Ocean (U.S. Weather Bureau, 1943).

	Jan.	Feb.	Mar.	Apr.	May	June	July
Total No. Observed	16	8	11	16	29	40	128
Average per month	0.4	0.2	0.3	0.4	0.7	1.0	3.2
	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	
Total No. Observed	169	142	130	67	46	802	
Average per month	4.2	3.6	3.2	1.7	1.2	20.1	

Table 14.--Characteristic properties of zonal currents through the section at long. 137°E in January 1967, RV Ryofu Maru (Masuzawa, 1967).

Current		Range	Width (mile)	Difference of sea surface (dyn. cm)	Geostrophic flux (km ³ • hr ⁻¹)
Kuroshio		Ry 3031-Ry 3035 33°30'N-31°20'N	130	- 117	+ 273
Kuroshio Countercurrent		Ry 3035-Ry 3038 31°20'N-28°54'N	146	+ 47	- 162
Subtropics		Ry 3038-Ry 3045 28°54'N-21°58'N	416	- 16	+ 0.3
North	Northern part	Ry 3045-Ry 3052 21°58'N-14°54'N	424	+ 10	- 79
Equatorial	Southern part	Ry 3052-Ry 3060 14°54'N-06°58'N	476	+ 45	- 145
Current	Whole	Ry 3045-Ry 3060 21°58'N-06°58'N	900	+ 55	- 224
Equatorial Countercurrent		Ry 3060-Ry 3065 06°58'N-02°04'N	294	- 28	+ 234
Equatorial Undercurrent?		Ry 3065-Ry 3070 02°04'N-00°43'S	167	...	...

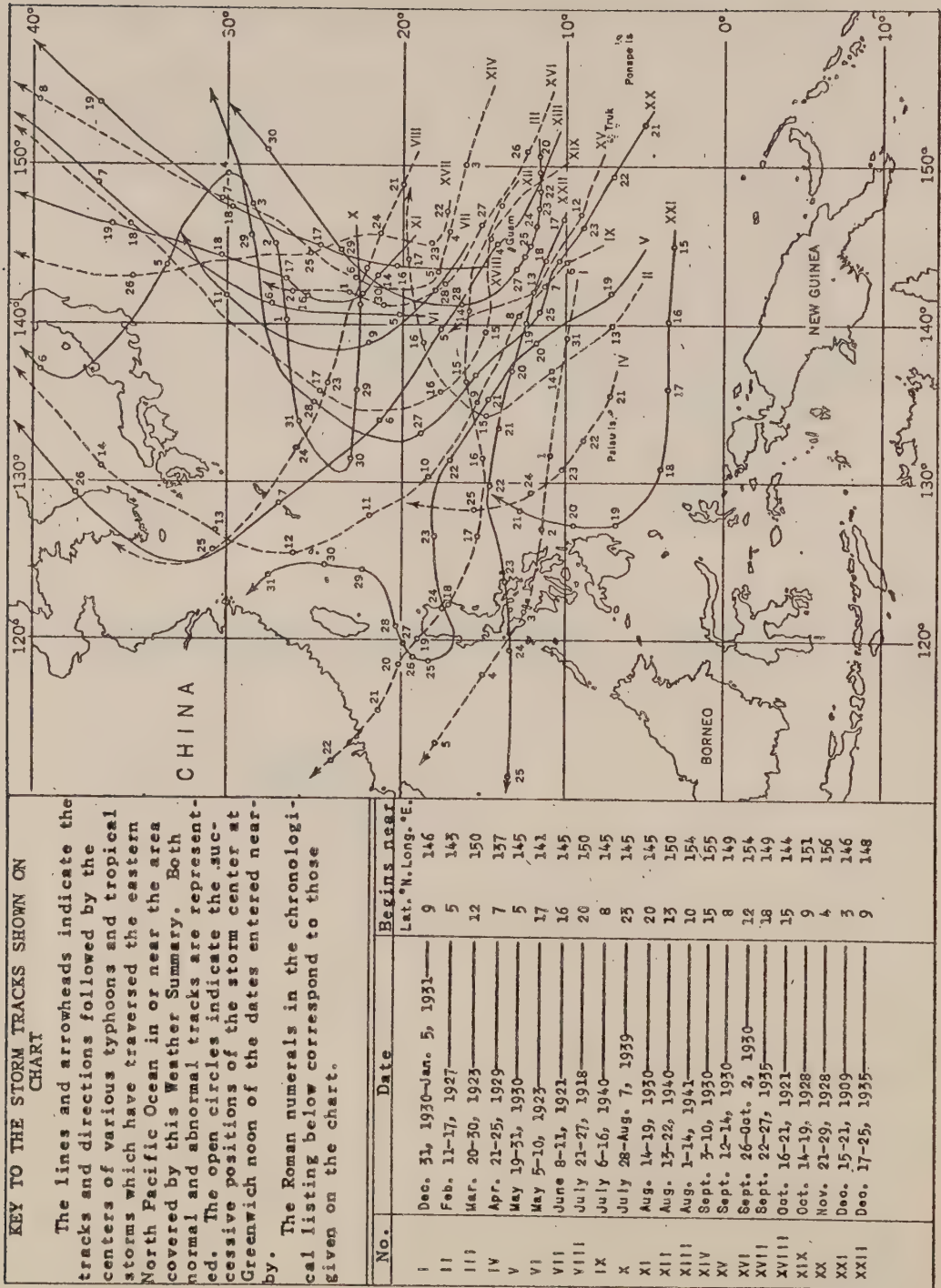


Figure 22.--Selected tracks of typhoons of the western North Pacific (U.S. Weather Bureau, 1943).

Typhoons vary in diameter (U.S. Weather Bureau, 1943). Some are small, perhaps less than 50 mi (93 km) across, but others have diameters of 300 to 500 mi (556 to 926 km) or more. The center or eye of the typhoon is rarely less than 6-7 mi (11-13 km) and not much larger than 20-25 mi (37-46 km).

Among the Carolines and Marianas, typhoons usually approach from the east or southeast, but rarely from the south (U.S. Weather Bureau, 1943). Most likely, the storms cross the Marianas in July-October and the Western Carolines in May-June and November-December.

Data from individual islands or island groups within Micronesia show the frequency and season of thunderstorms and typhoons. In Palau, which averages 22 storms per year, there is usually 1 per month in January-April and 2-3 monthly in May-December (U.S. Weather Bureau, 1943). Thunderstorms usually occur more frequently after June because at this time the ITCZ moves northward across the islands. Palau lies just below the beginning of the typhoon belt and rarely has real typhoons.

Thunderstorms are relatively infrequent at Yap (EDS, 1973f). They occur in association with the ITCZ as it moves northward in July and southward again in October in the vicinity of Yap; therefore, June to November is the period of most frequent storms (U.S. Weather Bureau, 1943; EDS, 1973f). In August-December, the average is about two per month. Tropical cyclones are more prevalent further to the northwest. June-December is when typhoons occur in greatest frequency although fully developed ones are uncommon near Yap. Most of the typhoons near Yap pass to the north, then move westward or northwestward away from the island.

Between July and November, Truk and Ponape are frequently under the influence of the ITCZ which has moved northward into the vicinity of these island groups, and during this period tropical disturbances and moist southerly winds are most frequent (EDS, 1973d, 1973e). Truk and Ponape are located within the spawning grounds of typhoons, but the major typhoon tracks in the western Pacific lie well to the north and west. Typhoons Lola in November 1957 and Ophelia in January 1958 caused extensive damage to crops and housing on Ponape (EDS, 1973d). At Truk, these two typhoons brought winds of 70 mi/h (113 km/h) and caused widespread damage to buildings, crops, and coconut palms. Damages to coastal structure by storm-generated waves were also extensive (EDS, 1973e). On 1 May 1971, typhoon Amy moved directly over Truk lagoon. Winds from the south measured 78 mi/h (126 km/h) and a peak gust from the northeast was 113 mi/h (182 km/h). Rainfall totaled 8 in. (20 cm). Homes and other buildings suffered extensive damage and 75%-80% of the crop was destroyed.

At Majuro, tropical storms are very rare; the last typhoon recorded from this atoll occurred in January 1914 (EDS, 1973c). At Jaluit, according to U.S. Weather Bureau (1943) reports, about 17 thunderstorms usually occur in a year with an average of 2 per month in June-September.

During the rainy season on Guam, which extends from mid-July to mid-November, there is frequently a breakdown of the trades (EDS, 1973a). On some days during these periods, the weather is dominated by westerly moving storm systems that bring heavy showers or steady torrential rain. Also, there are occasional typhoons which bring not only tremendous rains but also violent winds producing flooding of the low-lying coastal areas. The probability of having one or more typhoons pass sufficiently close to Guam to produce high winds and heavy rains is about one in three. In the past 50 years, typhoons have passed close to Guam in every month but their most frequent occurrence is in July-December. A typhoon that moves directly across Guam occurs once in about 8 years.

THE OCEANOGRAPHIC CLIMATE

In Micronesian waters, not only meteorological but also oceanographic properties show little apparent seasonal variation. In the following sections, we discuss sea-surface temperatures, thermocline depth, surface currents, and chemical properties of water surrounding the islands and atolls within the Trust Territory.

SEA-SURFACE TEMPERATURE

Figure 23 shows the monthly mean sea-surface temperature in the Pacific Ocean. According to LaViolette and Seim (1969), who computed monthly mean temperatures from data collected in various regions of the Pacific, the surface temperature data collected in Trust Territory waters show little variation throughout the year. In the Marshalls, the surface temperature throughout the year varied between 73° and 91°F (23° and 33°C). Temperatures were usually lowest in March-April and highest in September-October. Observations made in the Western Carolines and Marianas showed that the minimum temperature was about 75°F (24°C) and the maximum observed value slightly above 84°F (29°C). Temperatures were usually lowest in February and highest in August-September. The monthly variation of sea-surface temperature in selected regions of the western Pacific is shown in Figure 24.



Figure 23.--Monthly charts of mean sea-surface temperature (LaViolette, 1970).



Figure 23.--Continued.

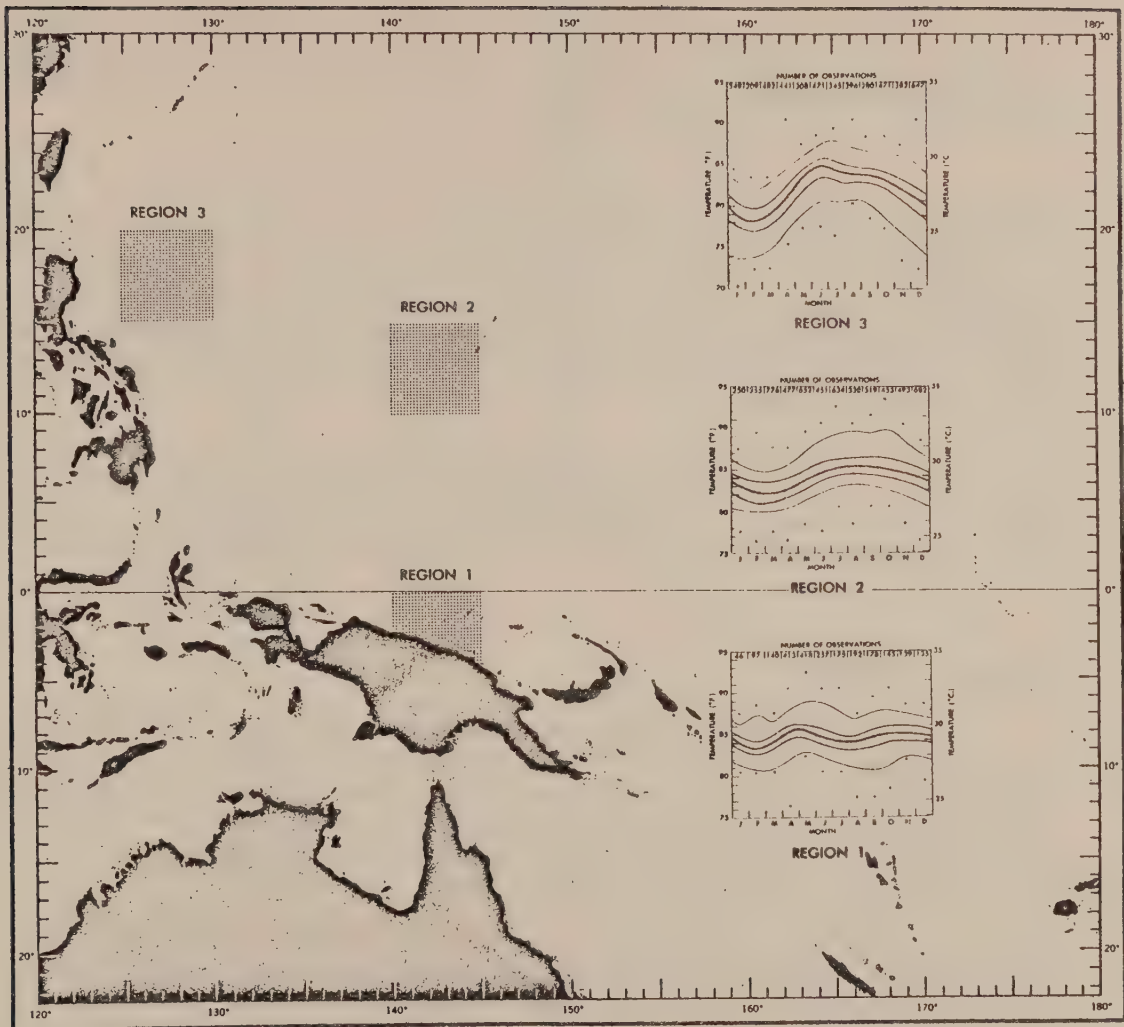


Figure 24.--Monthly variation of sea-surface temperature in selected regions. Dots represent the absolute extreme value reported; the inner (shaded) and outer (unshaded) envelopes represent 50% and 95% of the data observed (LaViolette, 1970).

Figure 23 also shows the latitudinal movement of the surface isotherms with season. Whereas the 78°-84°F (26°-29°C) isotherms are within the Micronesian area in March, they are displaced by the 84°-86°F (29°-30°C) isotherms by August.

The horizontal distribution of surface temperatures for the Marshall Islands area is shown in Figure 25. Mao and Yoshida (1955), in discussing some of the notable features, mentioned that the surface temperature in this area usually decreases slowly with increasing latitude. In summer, they detected somewhat lowered surface temperature at or near the equator and believed that intensive upwelling associated with equatorial divergence occurred (Figure 25). In the winter, however, the feature was not evident.

A tongue of cool water has its origin from the northeast and may be associated with the ascending motion in the northern boundary of the countercurrent. The temporal and spatial variation in the position of this tongue of cool water may be due to changes in wind pattern.

SURFACE CURRENTS

Two regions of trade wind current, one in each hemisphere, exist in the Pacific Ocean. These currents have a persistent westward drift during the entire year. The tangential stress of the trade winds, which embrace the major part of the world's ocean and blow persistently is responsible for the trade wind regions being the centers of action for surface circulation (Dietrich, 1963).

Schemes of the major oceanic circulation in the western Pacific in winter and summer are shown in Figures 26 and 27. In the western Pacific, not all the North Equatorial Current is directed north toward Japan or south into the South Pacific (Wiens, 1962). Some flows into the seas and basins of Indonesia and the Philippines to form local circulations. South of Palau, there is a major reversal of current direction and an eastward flow or countercurrent starts between the westward flowing North and South Equatorial Currents. The countercurrent, which extends nearly all the way across the Pacific, actually lies north of the equator, shifting latitudinally with the season. In February-March, the countercurrent flows south of the Western Carolines and between Ponape and Kusaie in the Eastern Carolines. Continuing eastward, the countercurrent then passes between the Marshalls and the northern Gilberts.

The westward flowing North Equatorial Current breaks up into complex gyral and cross currents as it flows among the various islands and atolls that lie in its path (Wiens, 1962). The seasonal monsoon

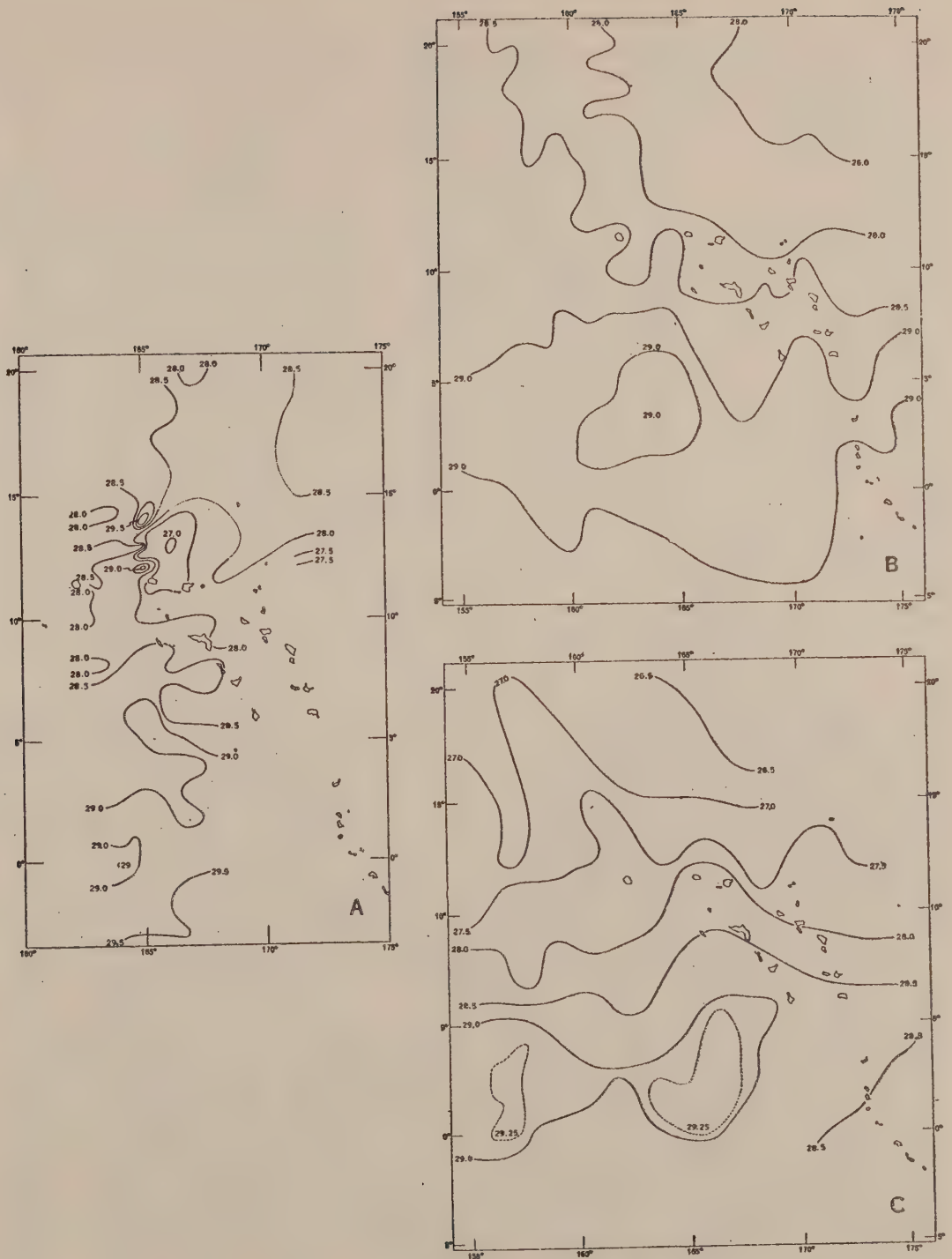


Figure 25.--Horizontal distribution of temperature at the surface. A. From Crossroads data, March to August 1946. B. From Japanese data, 1933-41 summer season. C. From Japanese data, 1933-41 winter season (Mao and Yoshida, 1955).

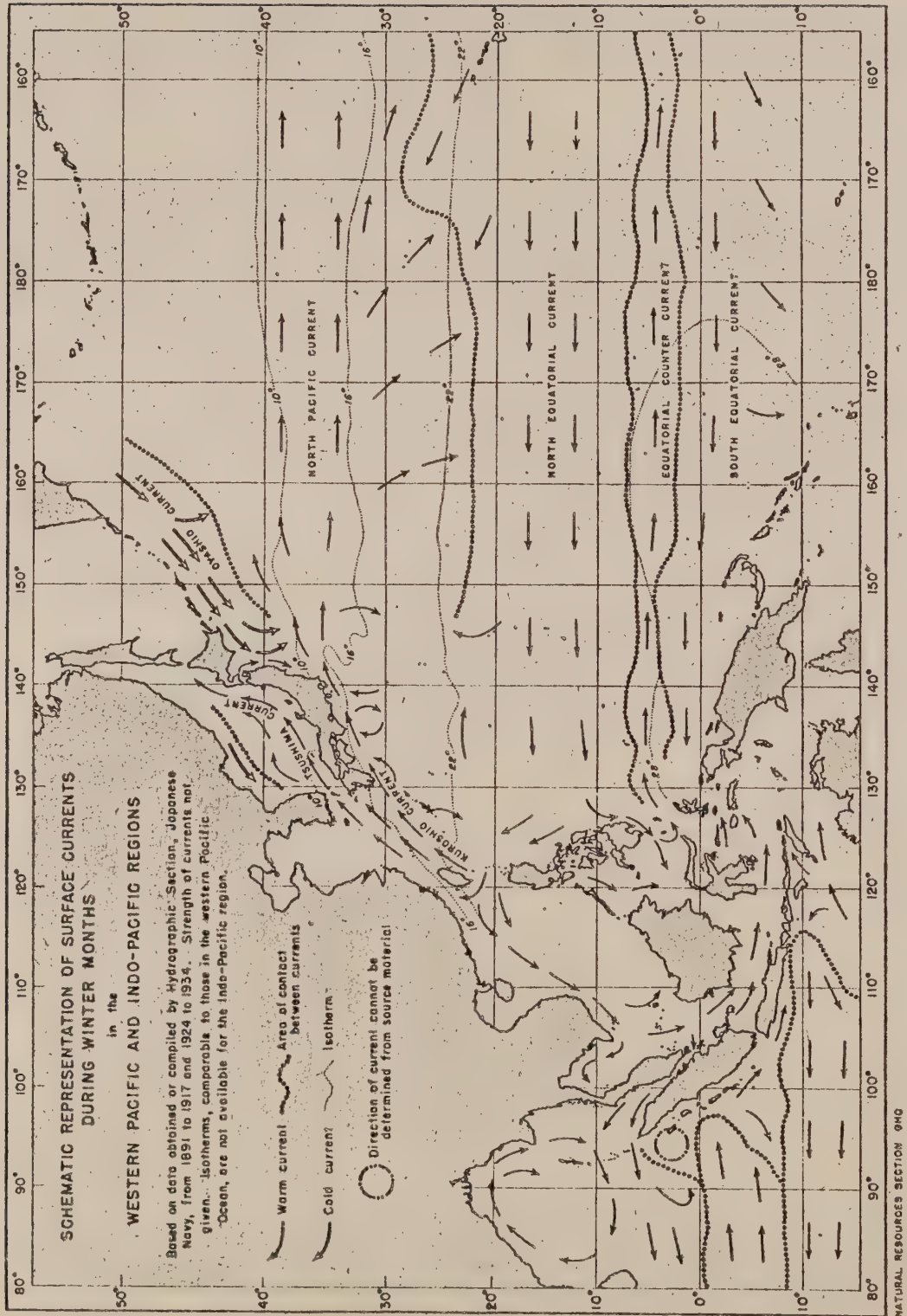


Figure 26.--Schematic representation of surface currents during winter months in the western Pacific and Indo-Pacific regions (Shapiro, 1948).

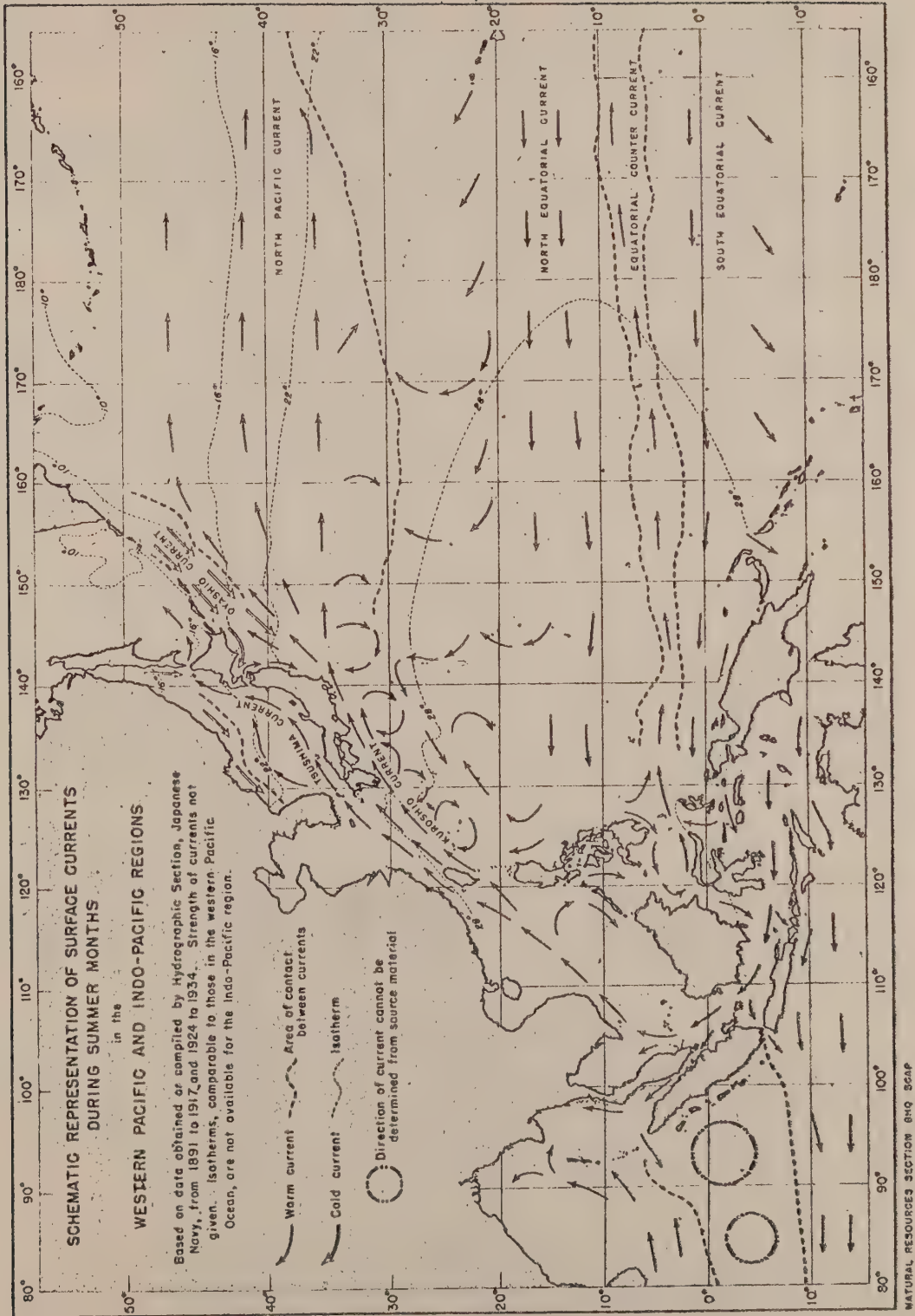


Figure 27.--Schematic representation of surface currents during summer months in the western Pacific and Indo-Pacific regions (Shapiro, 1948).

winds of east Asia also exert their influence; the strength of the Japan Current as well as the southeast-turning countercurrent near Palau vary with the seasonal monsoons.

To show greater detail in the waters around Micronesia, mean direction and force of the surface currents in each 1° quadrangle, and the current rose, which presents a graphical picture of the frequency of direction and the average drifts within the directions in each 5° quadrangle, are presented, by month, in Figures 28a to 28l (see Appendix 1 for explanation).

Because of the closeness of the Kuroshio, its countercurrent, and the subtropical currents to the currents which dominate the waters of Micronesia, we have included them in this discussion. A longitudinal oceanographic section, made from Japan to New Guinea along long. 137°E , was discussed by Masuzawa (1967). The oceanographic investigation, done in January 1967 aboard the RV Ryofu Maru, involved the Kuroshio, its countercurrent, weak currents in the subtropics, the North Equatorial Current, the Equatorial Countercurrent, and the Equatorial Undercurrent.

Figure 29 shows the track chart and stations of the CSK (Cooperative Study of the Kuroshio) cruise of the RV Ryofu Maru. Characteristic properties of zonal currents through a north-south section at long. 137°E are given in Table 14. The limits of the zonal currents were determined by the slope of the isobaric surfaces (Masuzawa, 1967). Three major zones were identified: The Kuroshio and its countercurrent between lat. $33^\circ28'$ and $28^\circ54'\text{N}$, the nearly currentless zone between lat. $28^\circ54'$ and $21^\circ58'\text{N}$, and the equatorial current system between lat. $21^\circ58'\text{N}$ and $00^\circ43'\text{S}$.

The northernmost zone, which embraces the Kuroshio, is most intense although narrow. South of the eastward flow of the Kuroshio is a well-defined westward flow between lat. $31^\circ18'$ and $28^\circ54'\text{N}$. This remarkable flow to the west probably is not a long continuous current independent of the Kuroshio but a clockwise eddy associated with the Kuroshio.

South of the Kuroshio countercurrent is a zone of weak or no current between lat. $28^\circ54'$ and $21^\circ58'\text{N}$ (Masuzawa, 1967). Here, weak eastward and westward currents appear alternately. Masuzawa found the most pronounced current in the upper 330 ft (100 m) to be an eastward flow at lat. 22° to 24°N and this current has been designated the "Subtropical Countercurrent" by some Japanese oceanographers.

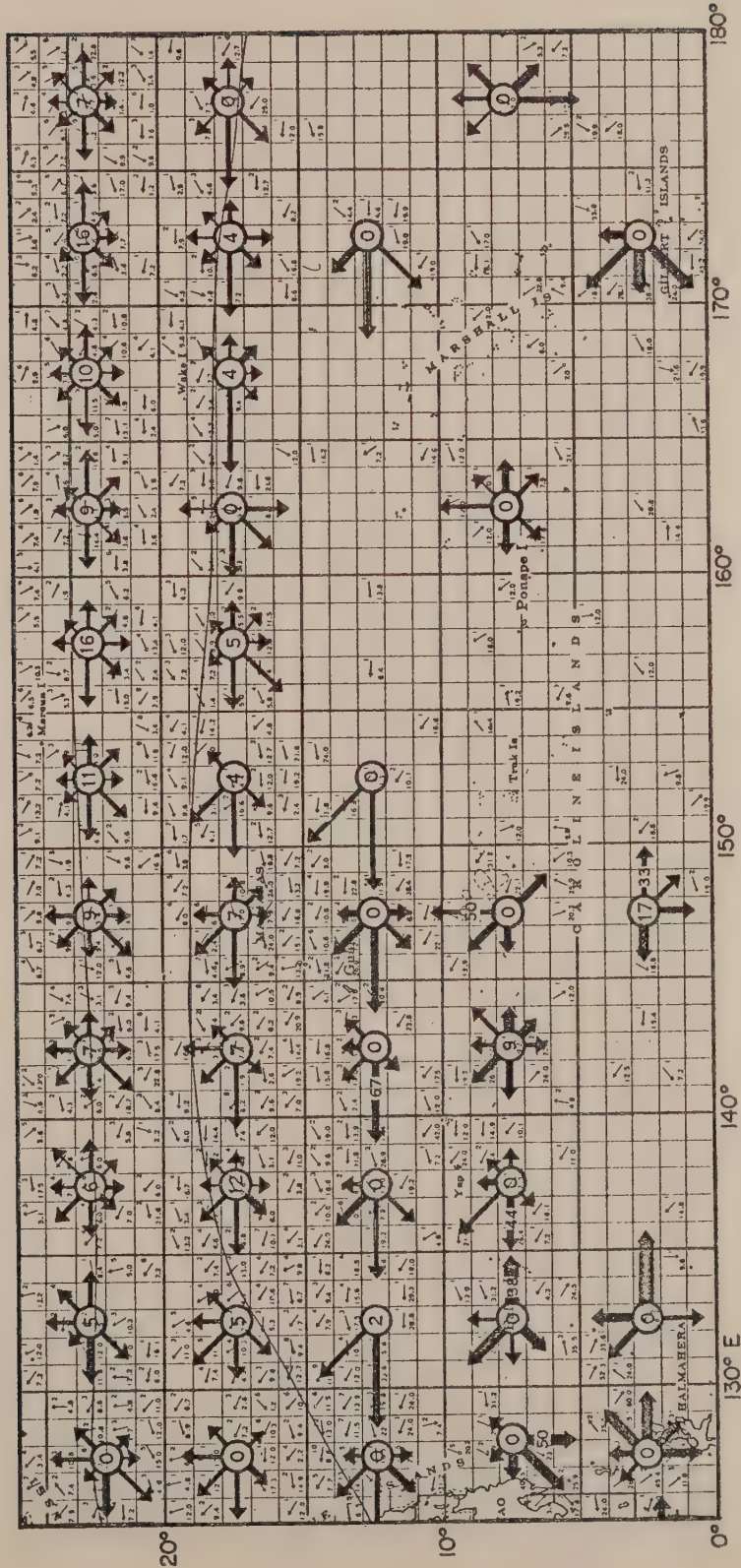


Figure 28a.--Surface currents in the northwestern Pacific Ocean in January (U.S. Navy Hydrographic Office, 1944).

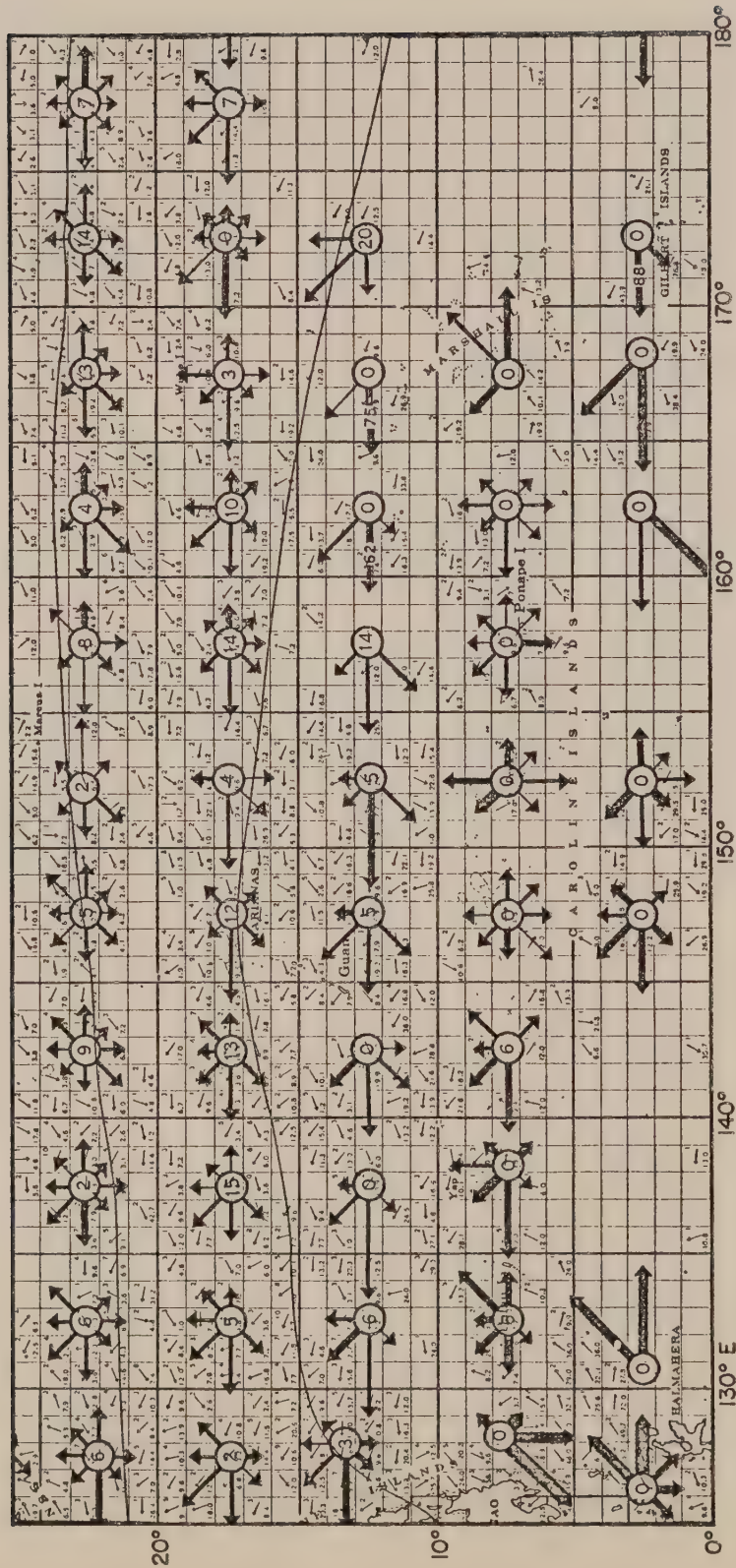


Figure 28b.--Surface currents in the northwestern Pacific Ocean in February (U.S. Navy Hydrographic Office, 1944).

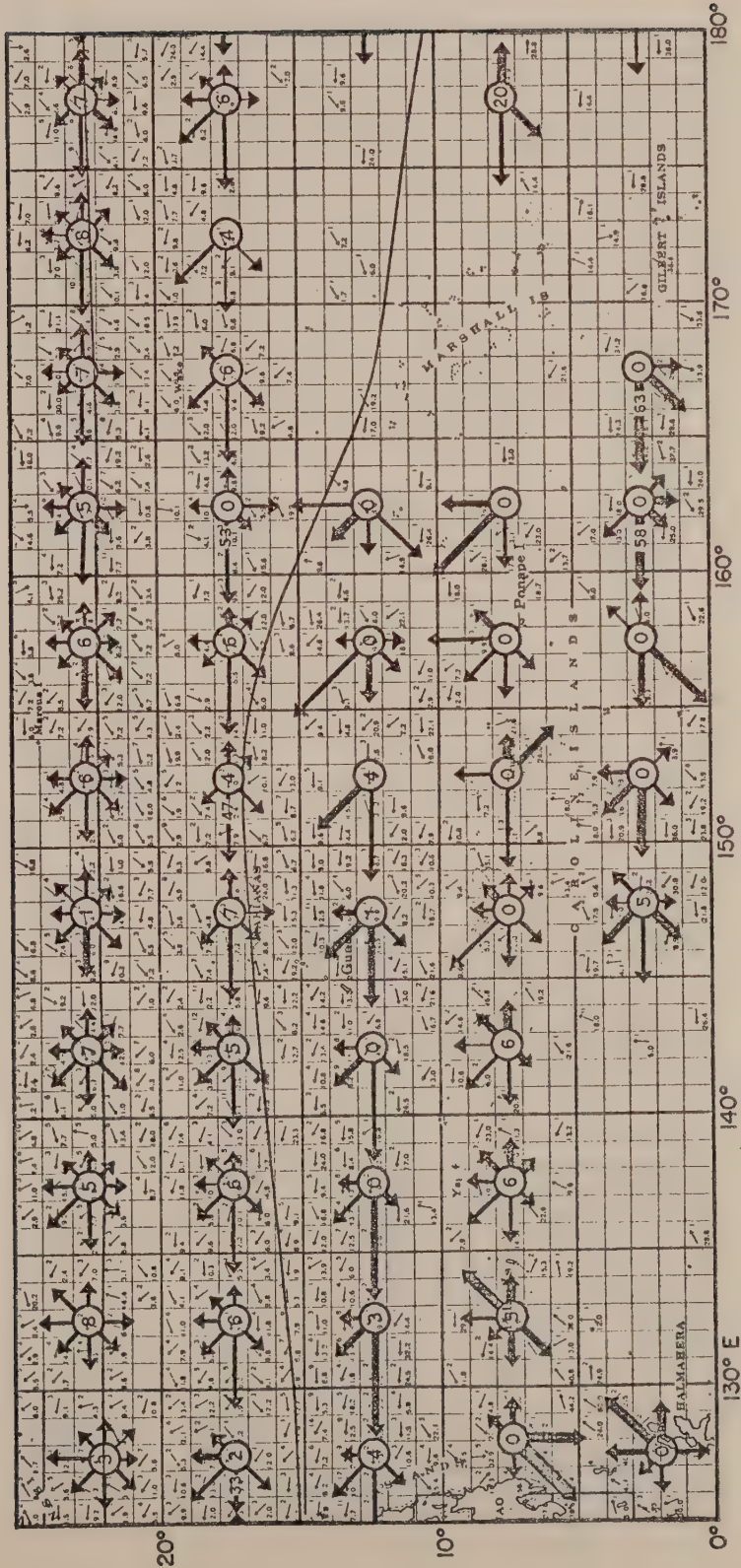


Figure 28c.--Surface currents in the northwestern Pacific Ocean in March (U.S. Navy Hydrographic Office, 1944).

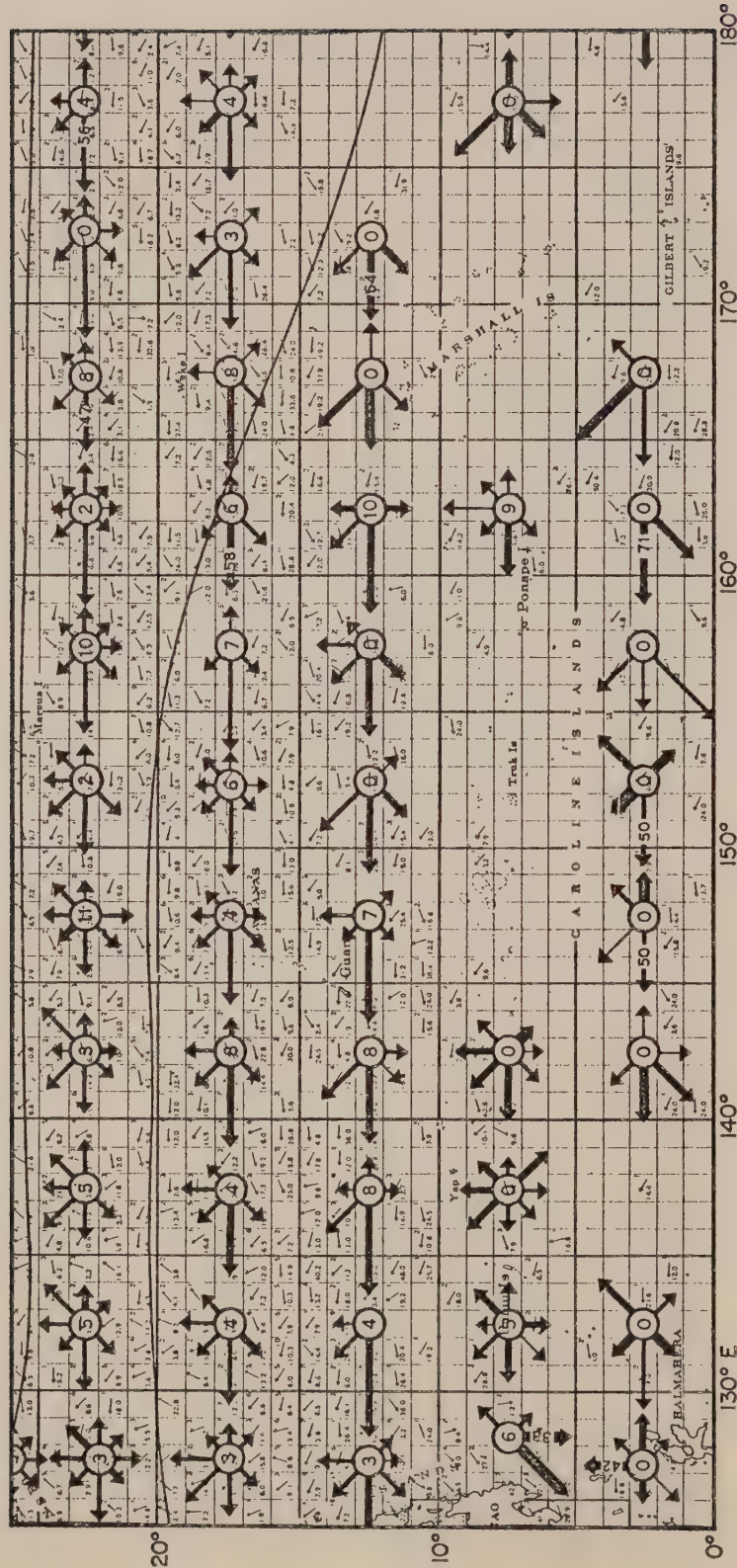


Figure 28d.--Surface currents in the northwestern Pacific Ocean in April (U.S. Navy Hydrographic Office, 1944).

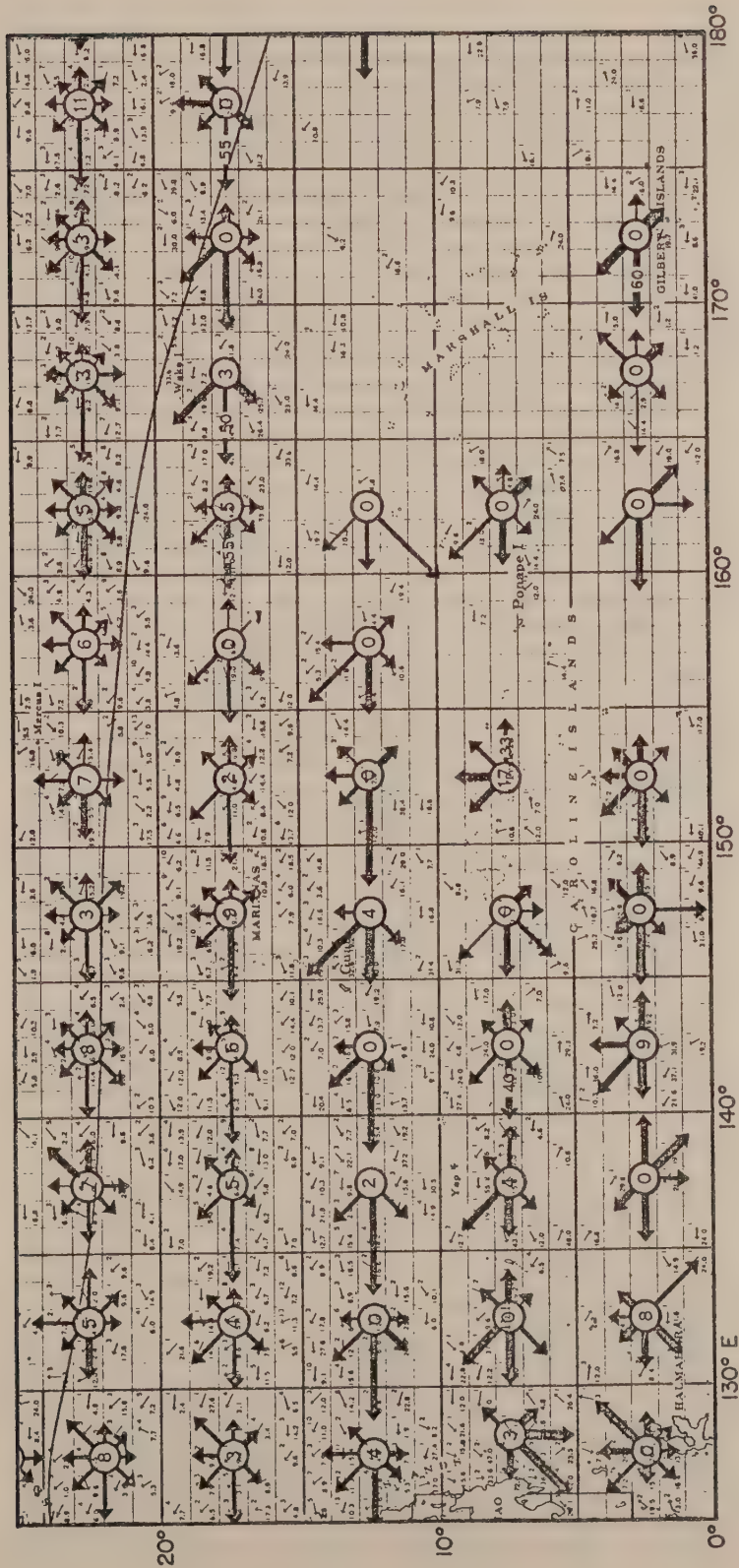


Figure 28e.--Surface currents in the northwestern Pacific Ocean in May (U.S. Navy Hydrographic Office, 1944).

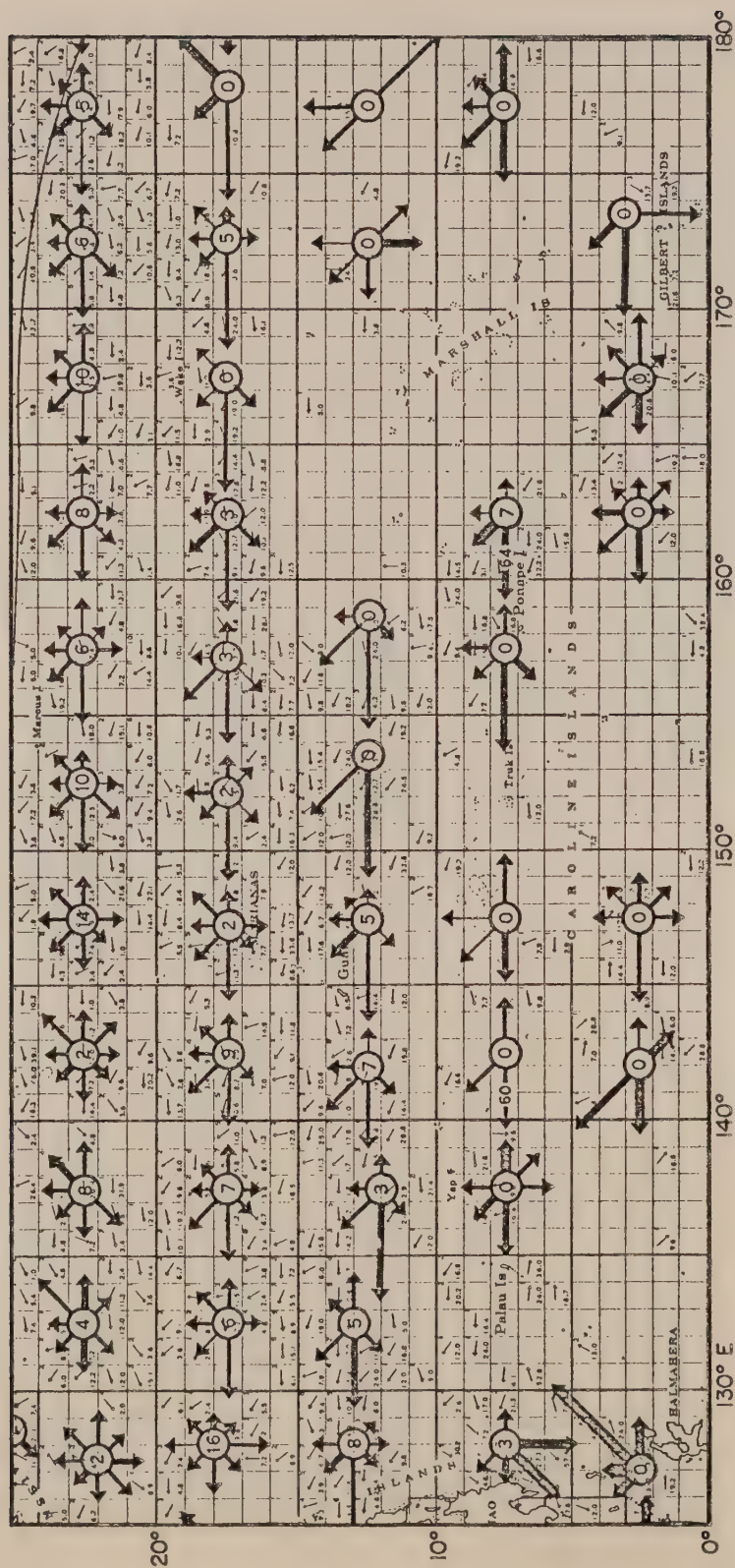


Figure 28f.--Surface currents in the northwestern Pacific Ocean in June (U.S. Navy Hydrographic Office, 1944).

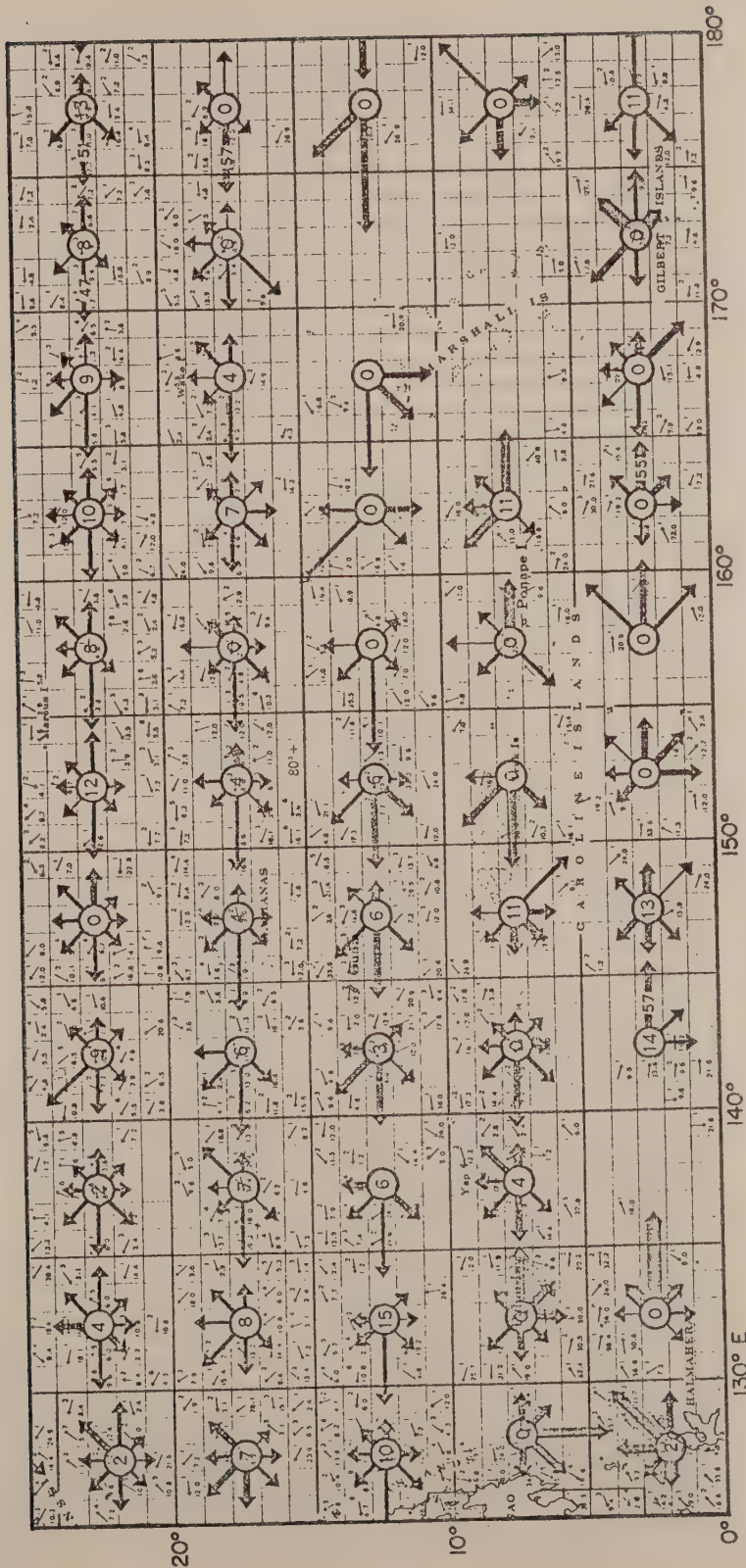


Figure 28g.--Surface currents in the northwestern Pacific Ocean in July (U.S. Navy Hydrographic Office, 1944).

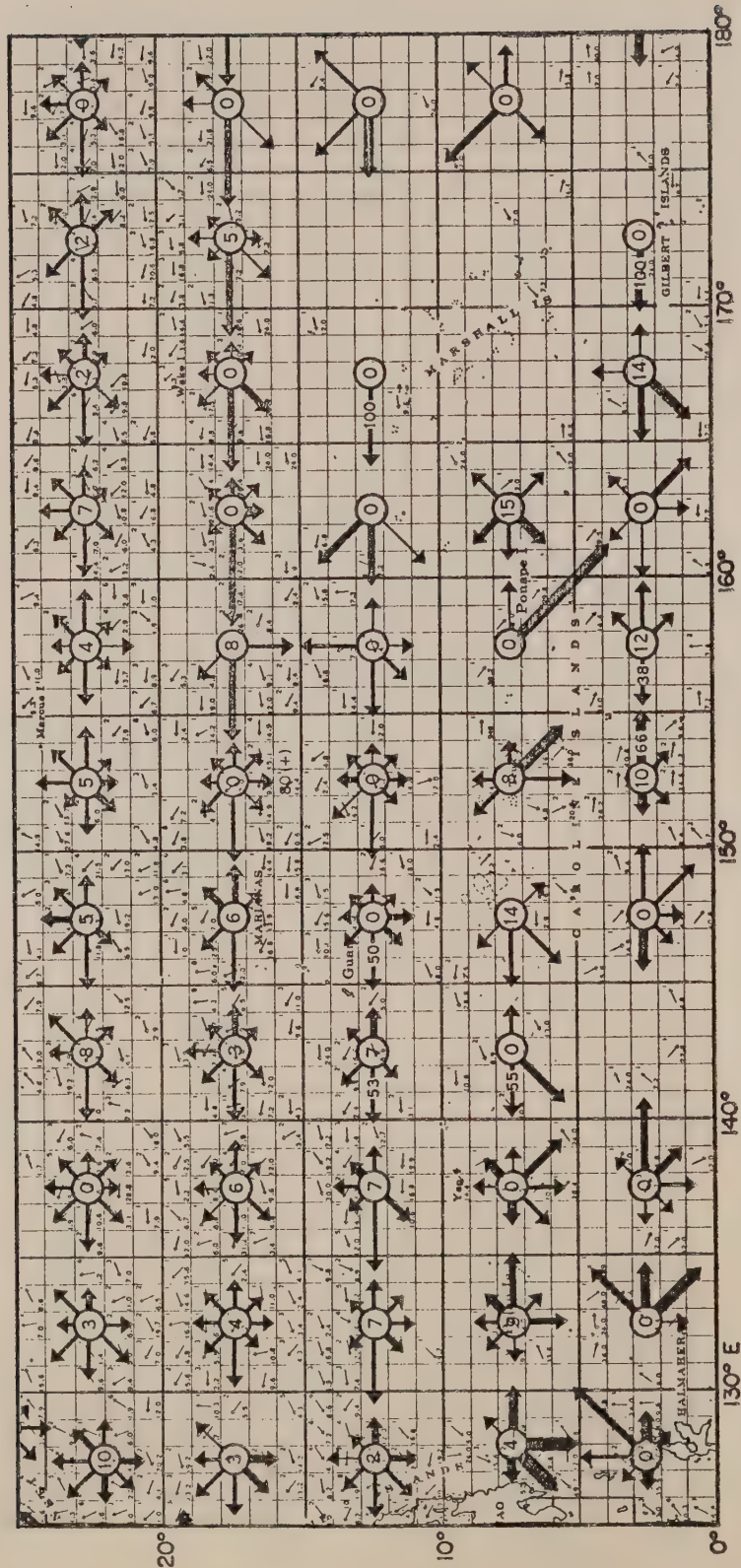


Figure 28h.--Surface currents in the northwestern Pacific Ocean in August (U.S. Navy Hydrographic Office, 1944).

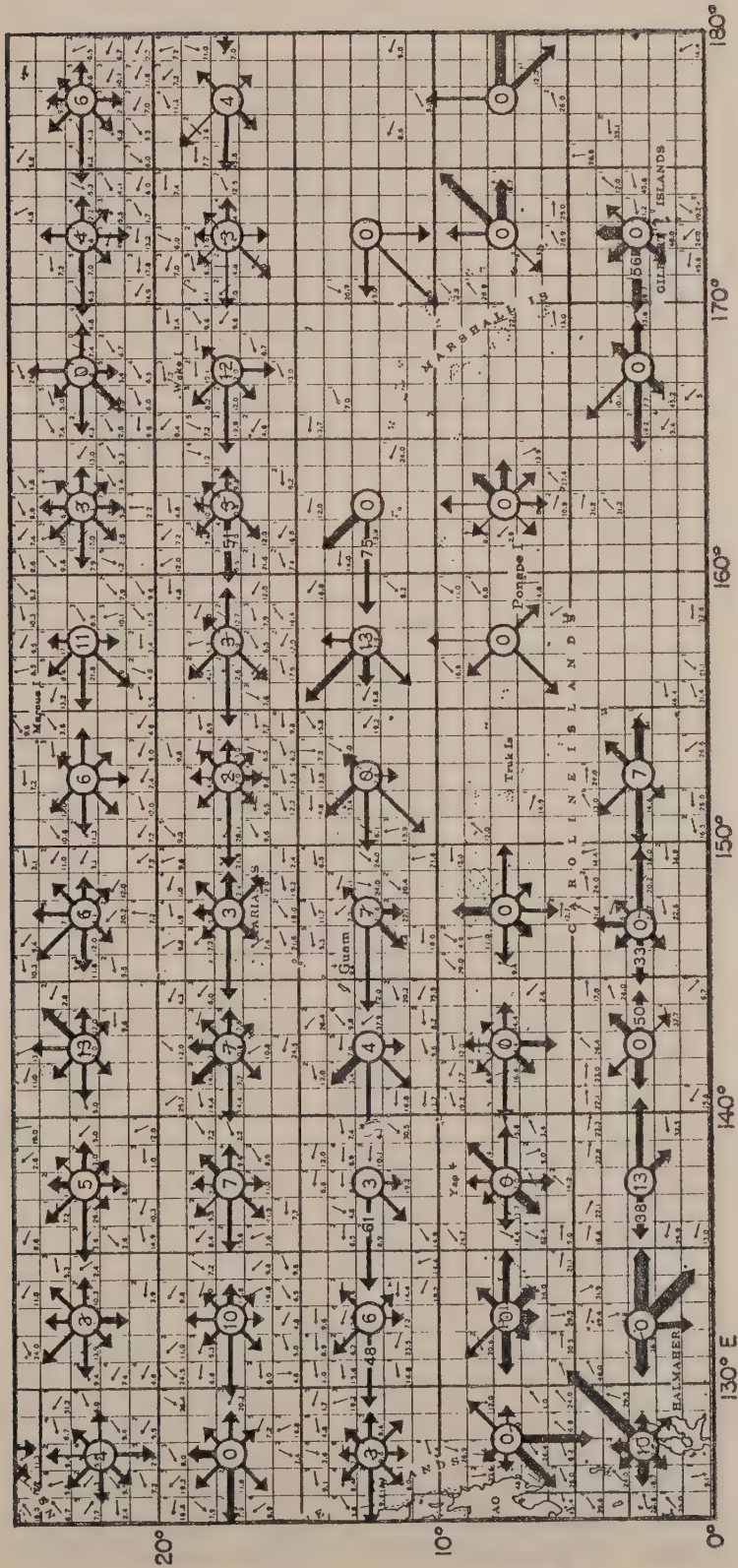


Figure 28i.--Surface currents in the northwestern Pacific Ocean in September (U.S. Navy Hydrographic Office, 1944).

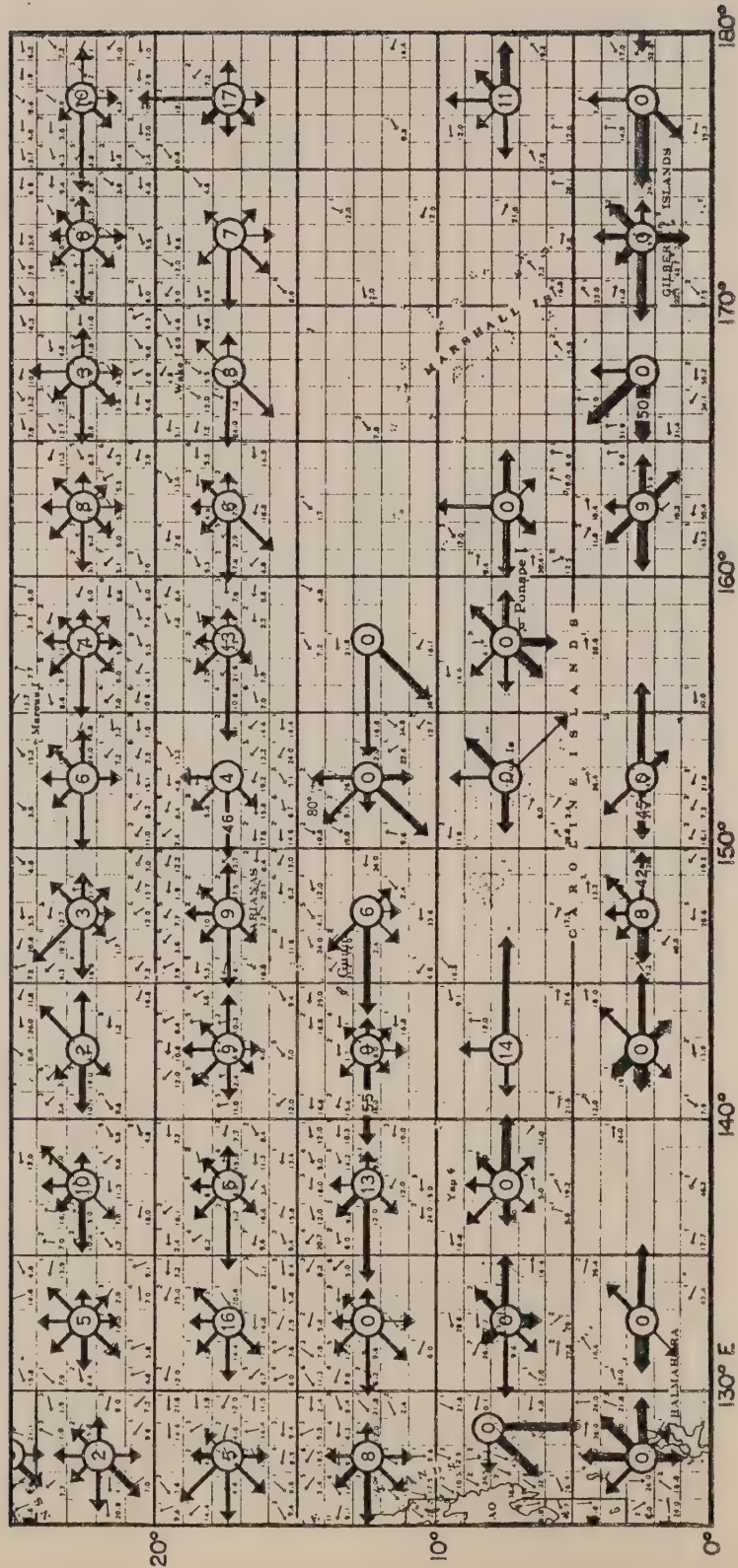


Figure 28j.--Surface currents in the northwestern Pacific Ocean in October (U.S. Navy Hydrographic Office, 1944).



Figure 28k.--Surface currents in the northwestern Pacific Ocean in November (U.S. Navy Hydrographic Office, 1944).

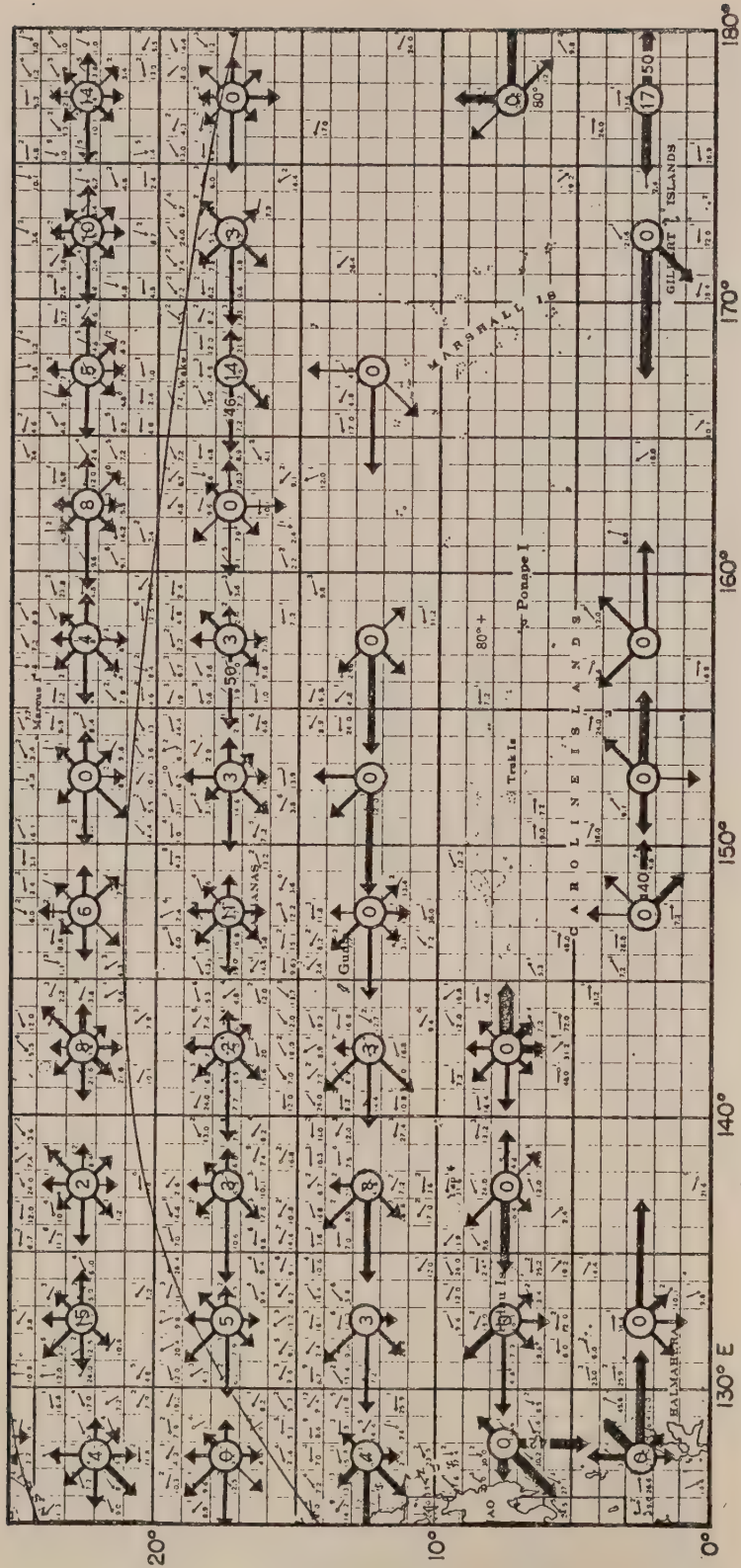


Figure 28.---Surface currents in the northwestern Pacific Ocean in December (U.S. Navy Hydrographic Office, 1944).

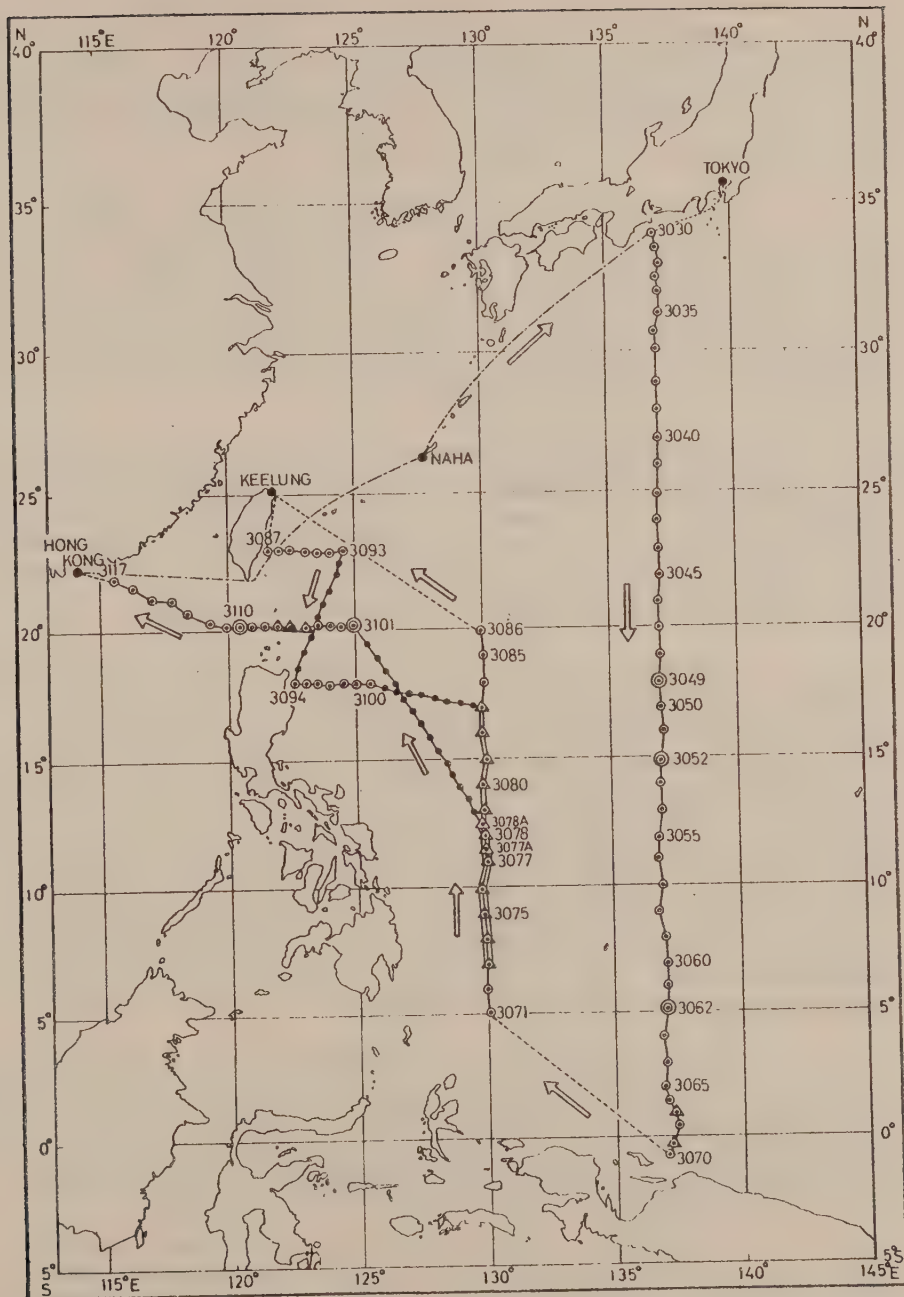


Figure 29.--Track chart of the CSK cruise of the RV Ryofu Maru, in January-March 1967 (Masuzawa, 1967).

Masuzawa (1967) recognized from the north-south sections that the North Equatorial Current could be split into two parts because of differences in the latitudes from which the slopes of the sea surface and isobaric surfaces began. The northern half was between lat. $21^{\circ}58'$ and $14^{\circ}54'N$ and the southern half between lat. $14^{\circ}54'$ and $6^{\circ}58'N$.

South of the North Equatorial Current is the countercurrent, which is between lat. $6^{\circ}58'$ and $2^{\circ}04'N$ (Masuzawa, 1967). Centered in the surface layer at lat. $4^{\circ}-5^{\circ}N$, it is not always clearly separated from the Equatorial Undercurrent, whose core lies 650-980 ft (200-300 m) deep near the equator. In the western Pacific, the Equatorial Undercurrent is not isolated from the countercurrent; in the central and eastern equatorial Pacific, it is.

One of the most important features of the current system in the Marshall Islands area is the existence of large-scale horizontal eddies between lat. 4° and $10^{\circ}N$, corresponding to the northern boundary of the countercurrent (Mao and Yoshida, 1955). These eddies have an approximate radius of several hundred kilometers. No eddies are found along the southern boundary of the countercurrent.

Mao and Yoshida (1955) proposed that these eddies are similar in nature to those found in the outer area of the Gulf Stream. When the countercurrent flows in the opposite direction to the surrounding currents, eddies are expected to be generated by cutoff from the meandering current system, that is, at the boundary zone between two different current systems. Another possibility is that the eddies are related to turbulence in this boundary zone. In such a zone, the current shear is very large and considerable horizontal mixing can occur. Under this condition, external disturbances, such as those caused by bottom topography, islands, or meteorological conditions, can produce eddies. Mao and Yoshida (1955) consider the effects of islands to be significant judging from the location of eddies.

The barrier effect of islands, interpreted another way, provides still another explanation for the formation of eddies. In the Marshalls, the Ratak and Ralik Chains are assumed to be barriers. Figures 30 and 31 depict how it is possible to produce eddies even where there is no significant turbulence or meandering.

Takahashi (1959) showed the existence and described the character of a "contra solem" vortex, which may be considered the western boundary vortex between the North Equatorial Current and the Equatorial Countercurrent. Located east of Mindanao Island in the Philippines, the vortex extends over an area 400 mi (741 km) in a north-south and 1,000 mi (1,853 km) in an east-west direction (Figures 32 and 33). The vortex is characterized by horizontal minimum temperature and salinity. Intermediate water, with a salinity minimum at

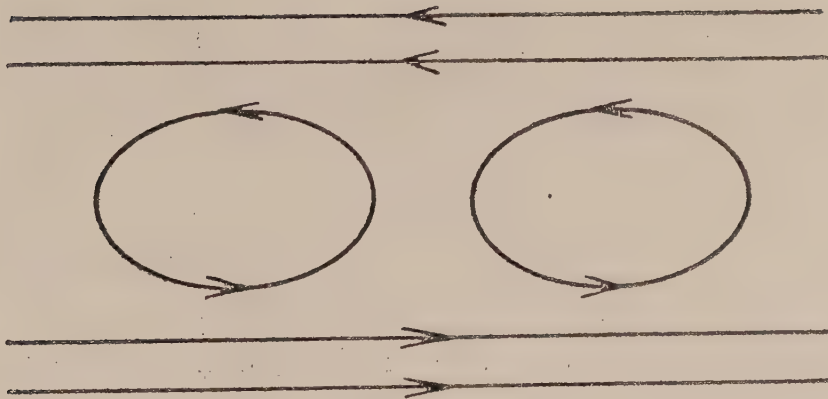


Figure 30.--A schematic representation of horizontal eddies produced in the boundary shear zone (Mao and Yoshida, 1955).

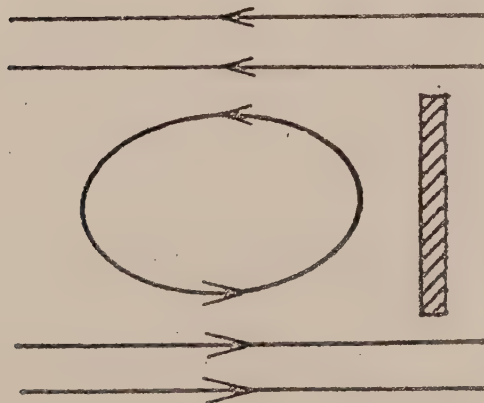


Figure 31.--A schematic representation of a horizontal eddy caused by a barrier (Mao and Yoshida, 1955).

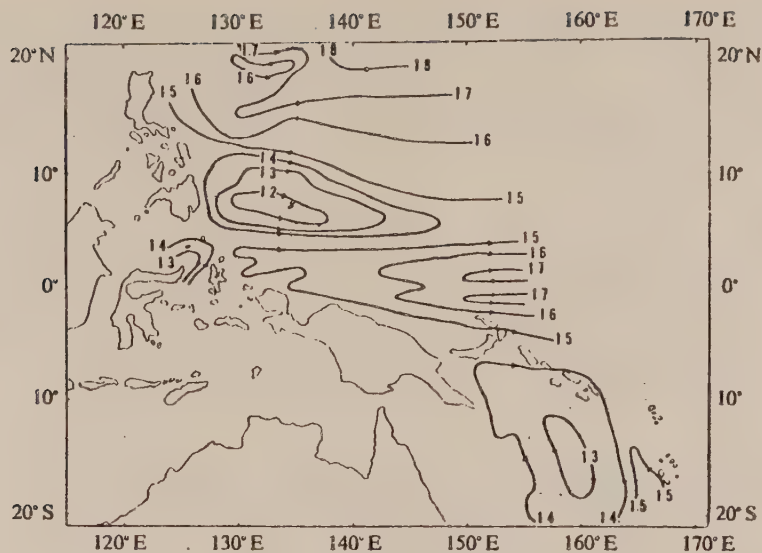


Figure 32.--Dynamic topography of the sea surface referred to the 500 decibar surface. Approximate current directions indicated by arrows (Takahashi, 1959).

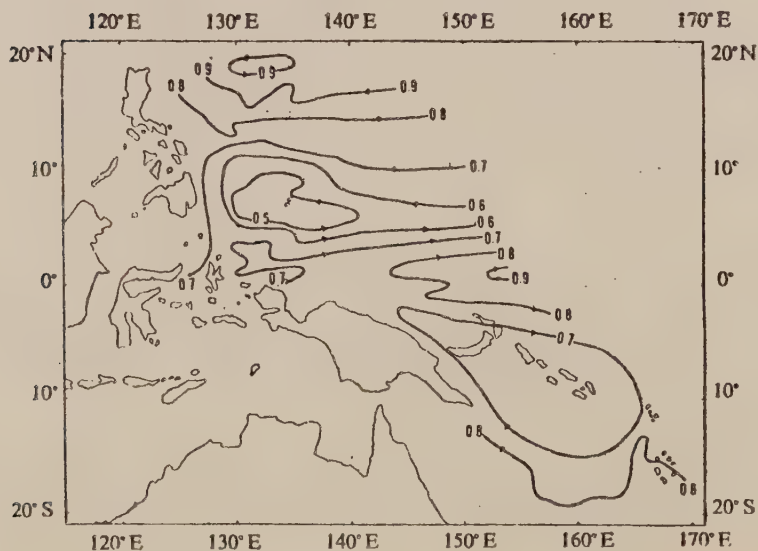


Figure 33.--Dynamic topography of 150 decibar surface referred to the 500 decibar surface. Approximate current directions indicated by arrows (Takahashi, 1959).

about 1,640 ft (500 m) almost vanishes in the vortex because of upwelling and mixing within this area. The maximum current velocity of about 3 knots occurs in the eastward flowing water on the southern part of the vortex. Another small vortex seems to exist around lat. 19°N within the North Equatorial Current.

THERMOCLINE DEPTH

There is evidence that suggests that temperature limits not only the horizontal distribution of tunas but their vertical distribution as well. Studying the rates of success with tuna purse seines in the eastern tropical Pacific tuna fishery, Green (1967) found that the success rate was clearly related to the depth of the thermocline and the average vertical temperature gradient within the thermocline. The success rate was 63.9% when the temperature gradient was large and the thermocline shallow; conversely, the combination of small gradient and deep thermocline gave a success rate of only 39.9%. Therefore, information on depth and temperature gradients of the thermocline may be useful in identifying areas where purse seining for tunas may be more successful.

On the cruise of MV Anela to the central and western Pacific to conduct exploratory pole-and-line fishing trials, Uchida and Sumida (1973) collected not only fishing but also environmental data. They found that while fishing around Majuro and Arno atolls in February, the thermocline was distinct and occurred between 200 and 330 ft (60 and 102 m). But by April very noticeable changes had occurred in the subsurface layer. The thermocline was shallower, with one trace showing it at 130 ft (40 m) and the other at 260 ft (80 m). And whereas the subsurface temperatures at 660 ft (200 m) were higher than 11°C in February, those observed in April were lower.

Figure 34 shows the approximate depth of the thermocline by means of contours drawn at depth intervals of 160 ft (50 m) (Sverdrup, Johnson, and Fleming, 1946). Of significance is the shallowness of the thermocline in the eastern Pacific, where a sharp temperature decrease is evident at depths of usually less than 160 ft (50 m). Toward the west the depth of the thermocline increases and in the western Pacific the minimum depth may vary between 490 and 660 ft (150 and 220 m).

Figure 35 shows the north-south variation in the thermocline at long. 137°E. Masuzawa (1967) stated that the main thermocline, centered at 50°-54°F (10°-12°C) north of lat. 15°N, slopes sharply downward from the northern edge of the Kuroshio to the southern edge, where the mixed layer is nearly isothermal and thickest over the

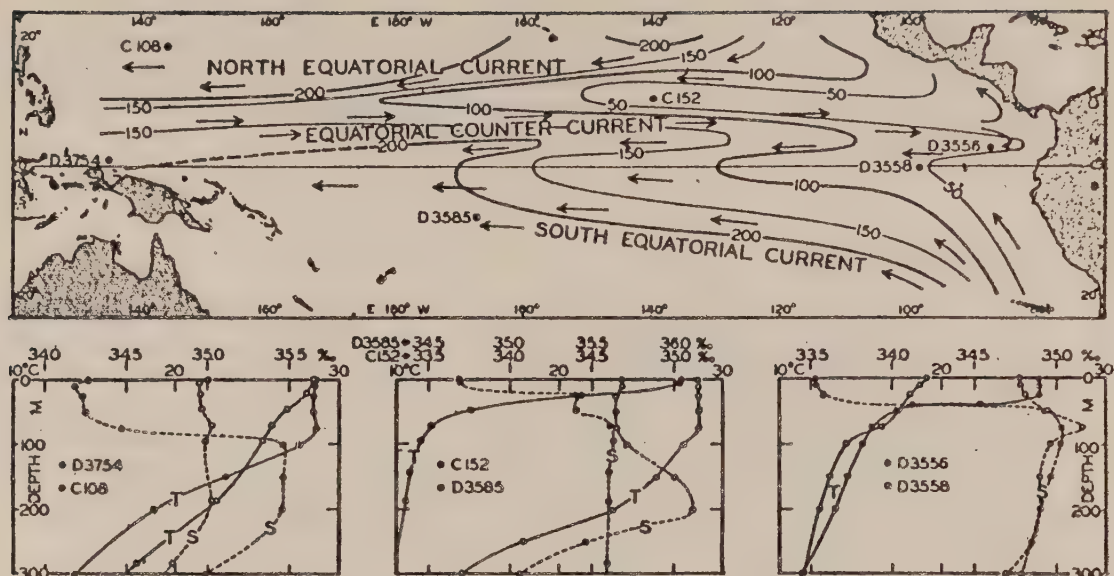
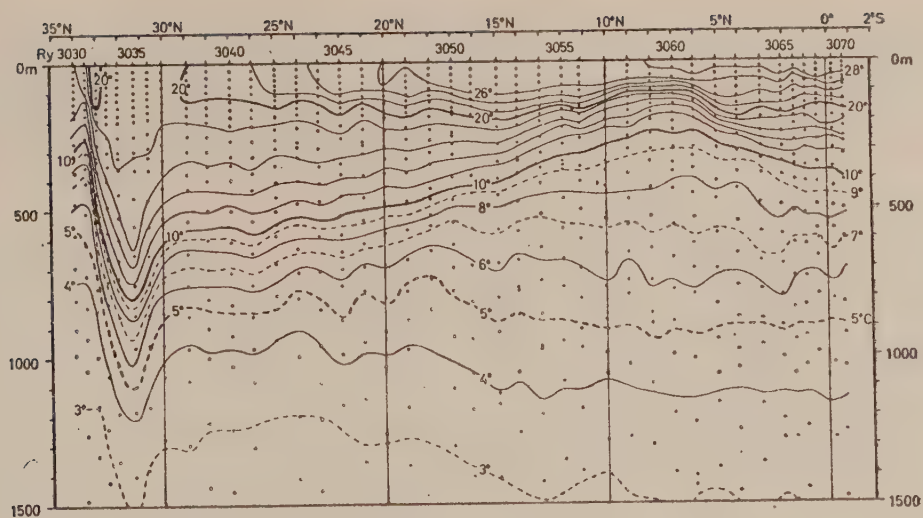
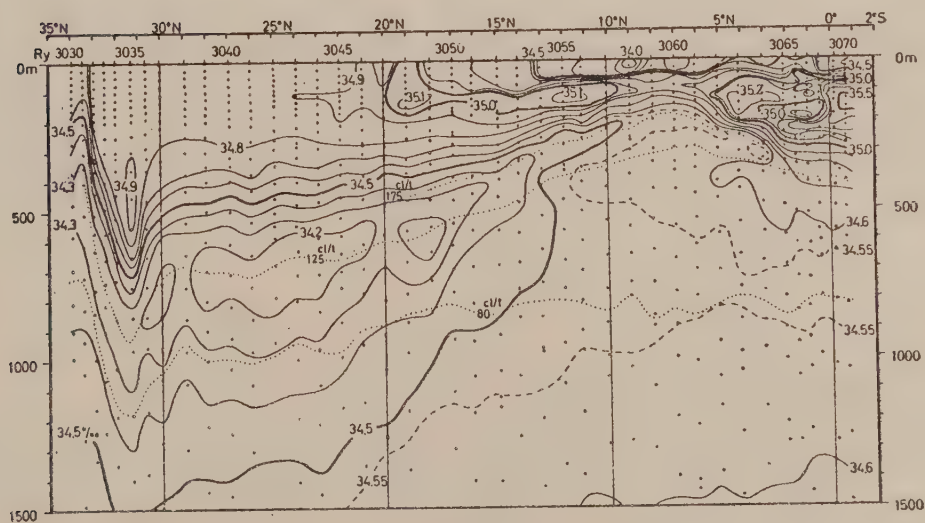


Figure 34.--Upper: Topography of the discontinuity surface in the equatorial region of the Pacific and corresponding currents. Lower: Vertical temperature and salinity curves at six stations, the locations of which are shown in the upper figure. Data are from Carnegie (C) and Dana (D) (Sverdrup, Johnson, and Fleming, 1946).

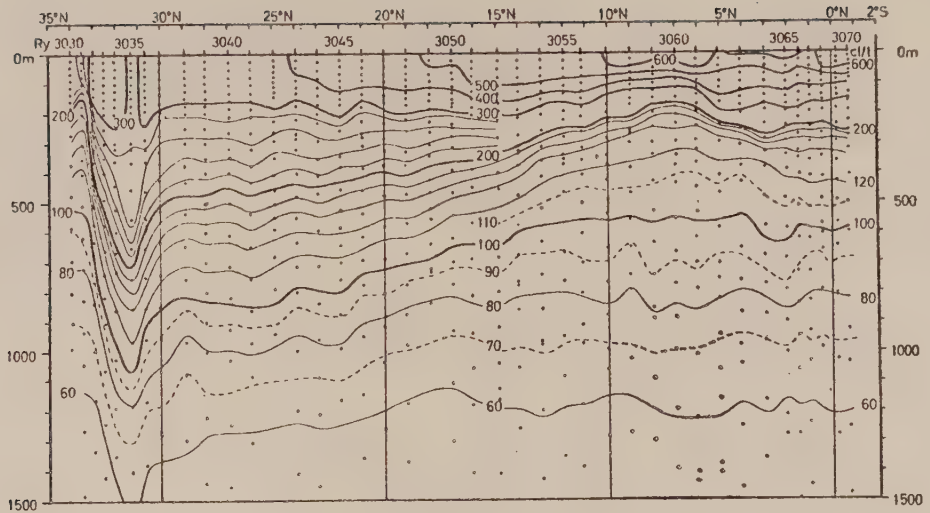


(a)

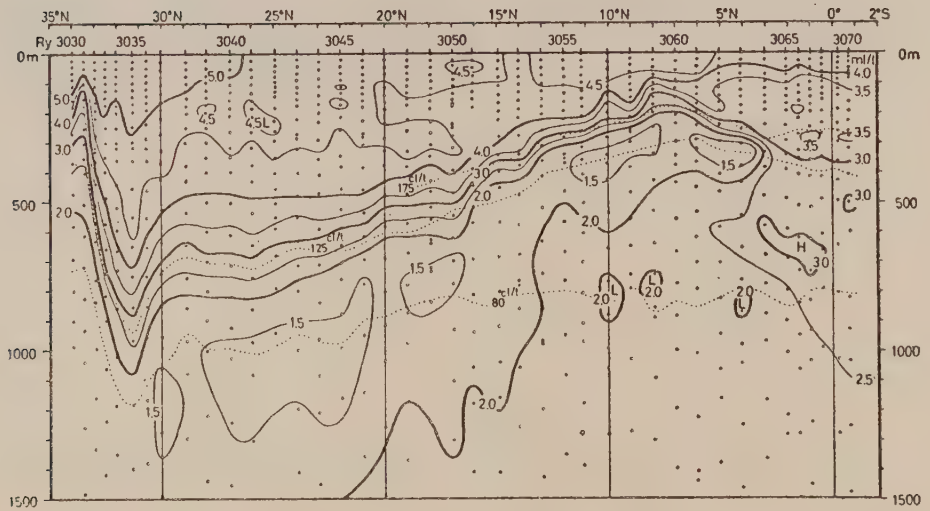


(b)

Figure 35.--Vertical sections of temperature (a), salinity (b),
thermosteric anomaly (c), and oxygen content (d) at long. 137°E
in January 1967 (Masuzawa, 1967).



(c)



(d)

Figure 35.--Continued.

section. Southward from lat. 30° to 15°N , the thermocline shallows gradually. At about lat. 15°N , the center of the thermocline is switched from 52°F (11°C) to about 68°F (20°C). The thermocline is shallowest and the vertical temperature gradient largest at the boundary between the North Equatorial Current and the countercurrent.

The temperature profile for the Marshall Islands area is shown in Figure 36. It can be readily seen that there are three parts: The topmost isothermal layer, the thermocline layer, and the layer of weak gradient. Mao and Yoshida (1955) found that in this region, the isothermal layer generally lies between 165 and 330 ft (50 and 100 m) with an average thickness of about 245 ft (75 m). The isothermal layer is somewhat thicker in winter than in summer. And there is a latitude dependence of the isothermal layer in this area; near the equator, it has a thickness of about 330 ft (100 m) or more. The shallowest depth occurs at about lat. 10° - 12°N in the summer and at about lat. 8° - 10°N in the winter.

The thermocline layer, indicated by the large gradient in the temperature profile in Figure 36 and by the crowding of isotherms in Figure 37, usually lies at 655 ft (200 m) for the area as a whole, varying between 245 and 985 ft (75 and 300 m) (Mao and Yoshida, 1955). The position of the shallowest thermocline appears roughly between lat. 5° - 9°N , which corresponds fairly well with the northern boundary of the countercurrent. Mao and Yoshida have also indicated that for the Marshalls area, the substitution of the 28°C isotherm for the thermocline is satisfactory for lat. 10° - 12°N or lower. For latitudes higher than 12°N , the thermocline is less distinct but the position of the 26°C isotherm appears to be a good approximation.

SALINITY AND OXYGEN

Figures 38a to 38d show the quarterly mean salinity at 10 m in the western Pacific Ocean. The outstanding feature of the horizontal distribution of salinity in the western equatorial Pacific is the separation of the northern and southern high-salinity regions by one of low salinity, usually located between lat. 0° and 10°N .

According to Cannon (1966), the low-salinity water which intervenes between the northern and southern tropical waters is also tropical water. He indicated that water with salinity less than 34‰ can be found in the eastern Pacific and that this water could be transported westward. Another part of the low-salinity tropical water apparently comes through the Molucca Passage from the east Indian Sea.

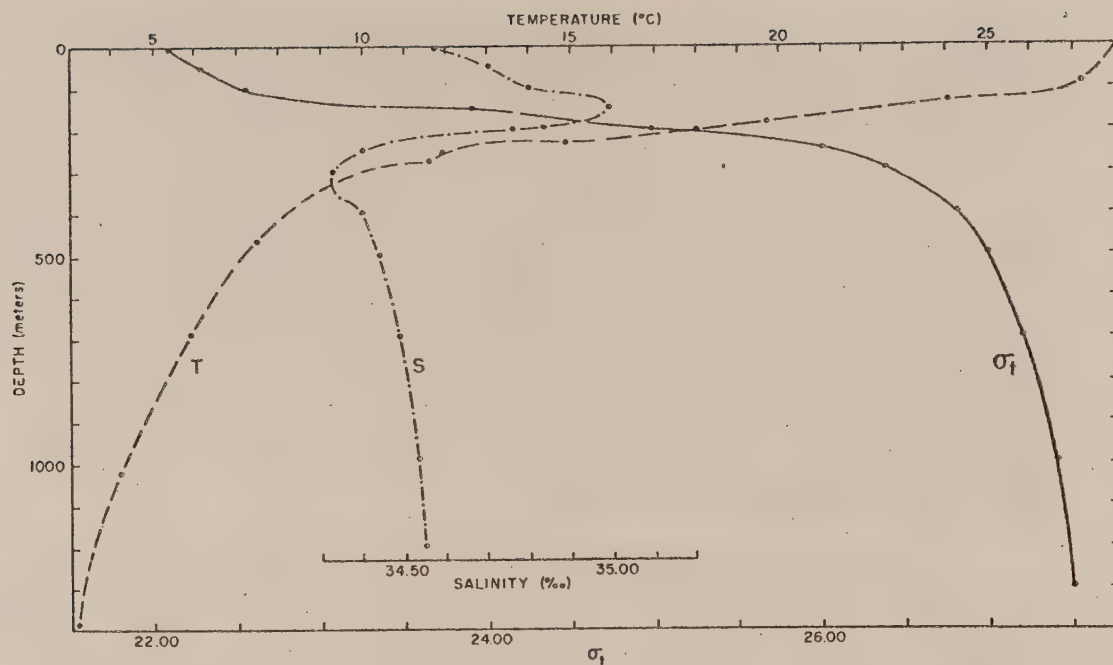


Figure 36.--Vertical distribution of temperature, salinity, and σ_t values at station B-39 (lat. $12^{\circ}00'\text{N}$, long. $168^{\circ}01'\text{E}$) from Cross-roads data, July 12, 1946 (Mao and Yoshida, 1955).

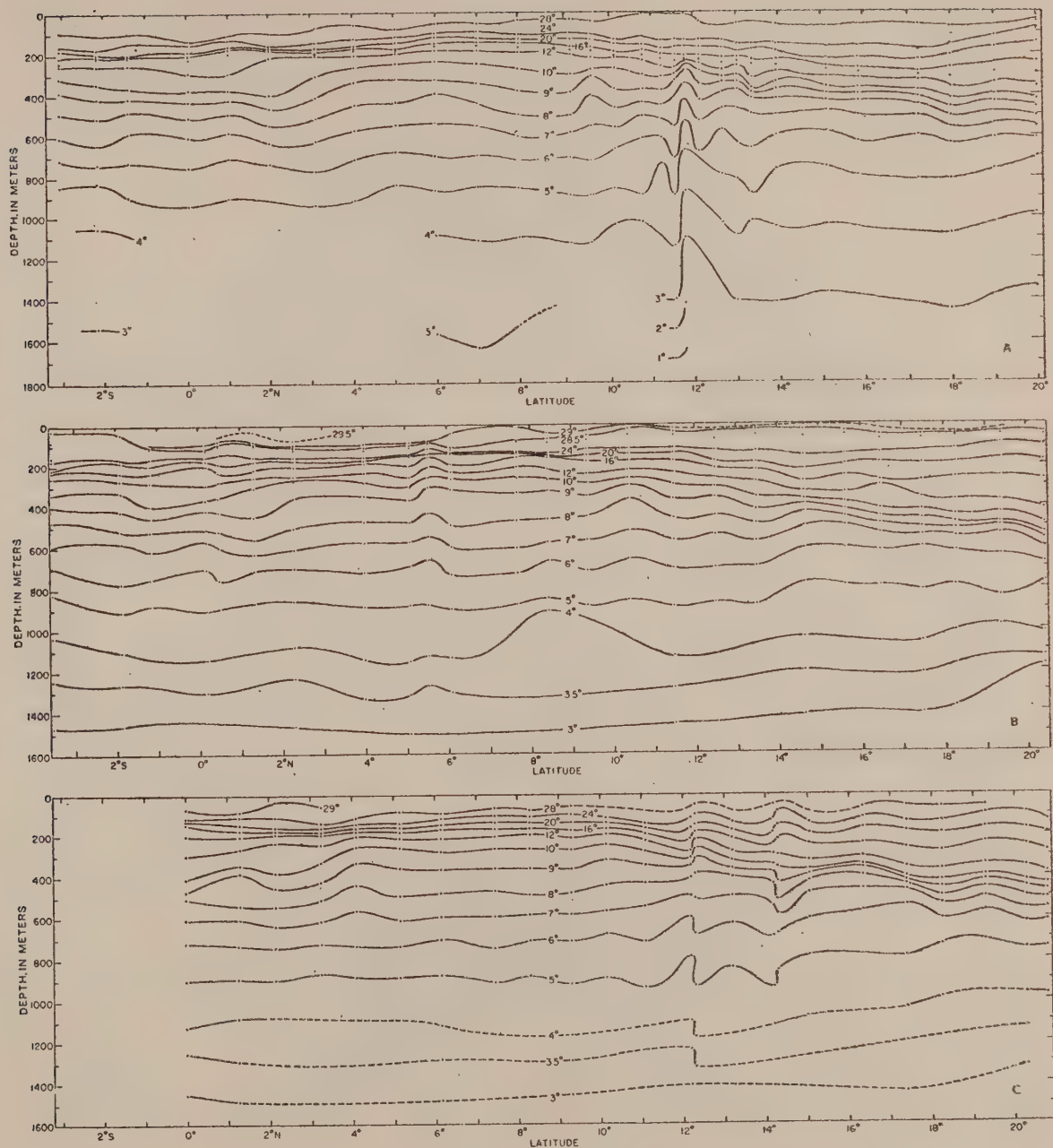


Figure 37.--Vertical distribution of temperature. A. From Crossroads data, March to August 1946. B. From Japanese data, 1933-41, summer season. C. From Japanese data, 1933-41, winter season (Mao and Yoshida, 1955).



Figure 38a.--Salinity (‰) at 10 m, first quarter (Barkley, 1968).

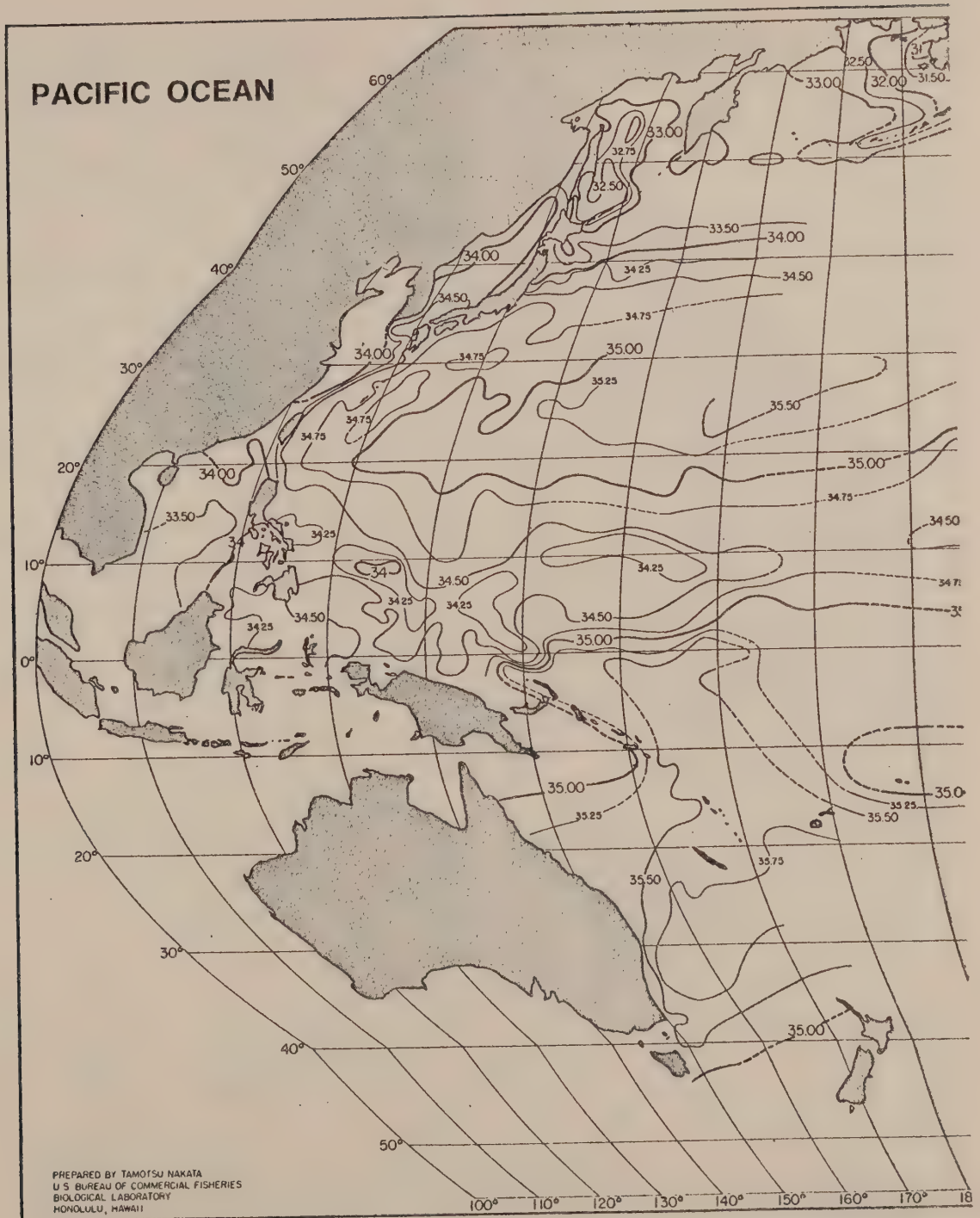


Figure 38b.--Salinity (‰) at 10 m, second quarter (Barkley, 1968).



Figure 38c.--Salinity (‰) at 10 m, third quarter (Barkley, 1968).



Figure 38d.--Salinity (‰) at 10 m, fourth quarter (Barkley, 1968).

In the Western Carolines along long. 137°E, Masuzawa (1967) found that the North Pacific tropical water with salinity exceeding 35‰ lies in the upper part of the thermocline between lat. 10° and 20°N and is in contact with the sea surface near lat. 19°N (Figure 39). Saline water originating in the South Pacific is also detected in the Western Carolines and extends as far north as lat. 6°N near the northern boundary of the countercurrent. The North Pacific major salinity minimum can be traced from the coast of Japan as far south as lat. 15°N.

In the Marshalls, Mao and Yoshida (1955) found that the most outstanding feature of the horizontal distribution of salinity is the presence of a low-salinity band of low temperature at about lat. 5°-10°N or about where the large eddies exist (Figure 40). Waters of high salinity push toward this band of low salinity from both sides. The gradient on the southern side suggests that the strongest influx of high-salinity water comes from the southern hemisphere.

Mao and Yoshida suggested that the band of low-salinity water results from high precipitation, absence of saline tropical water from the north and south at these latitudes, ascent of the northern intermediate water mass with decreasing latitude, and upwelling associated with currents and eddies. They assumed that upwelling, which originates at some intermediate depth, brings cool and fresh water into the upper levels. The ascending northern and southern intermediate water masses may further strengthen this upwelling.

In the Marshall Islands area, the salinity profile, shown in Figure 36, has a topmost layer, the upper layer (characterized by salinity maximum), the intermediate layer (characterized by salinity minimum), and the deeper layer (characterized by weak salinity gradient). Figure 41 shows the vertical salinity distribution characterized by high- and low-salinity tongues of water coming into the area from both north and south (Mao and Yoshida, 1955). The two tongues of high-salinity water correspond to tropical water (salinity maximum) whereas the two tongues of low-salinity waters represent intermediate water (salinity minimum) (Cannon, 1966).

The saline tropical water originates in the tropics where evaporation is usually high (Mao and Yoshida, 1955). This water is warm and, therefore, its density relatively low. The depth of the salinity maximum corresponds to the central axis of the two saline tropical waters at a depth of about 490 ft (150 m). Comparison shows that the southern tongue is the more saline, reaching 35.60‰ to 36.80‰ whereas the salinity in the northern tongue rarely exceeds 35.50‰.

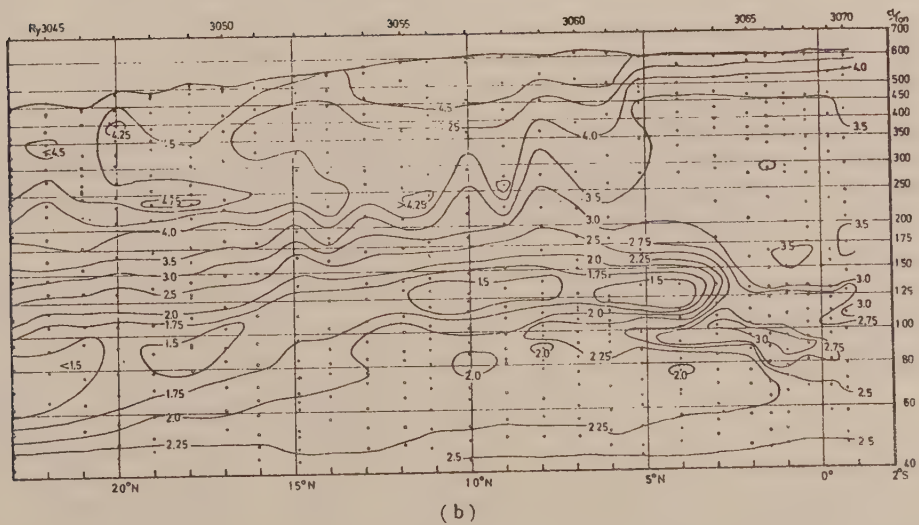
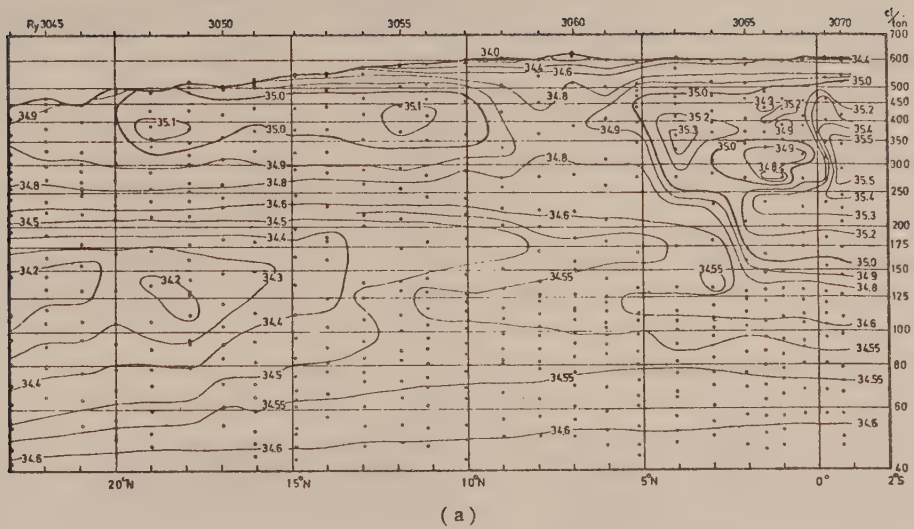


Figure 39.--Meridional sections of salinity (a) and oxygen content (b) against thermobaric anomaly in logarithmic scale in the equatorial current system at long. 137°E in January 1967 (Masuzawa, 1967).

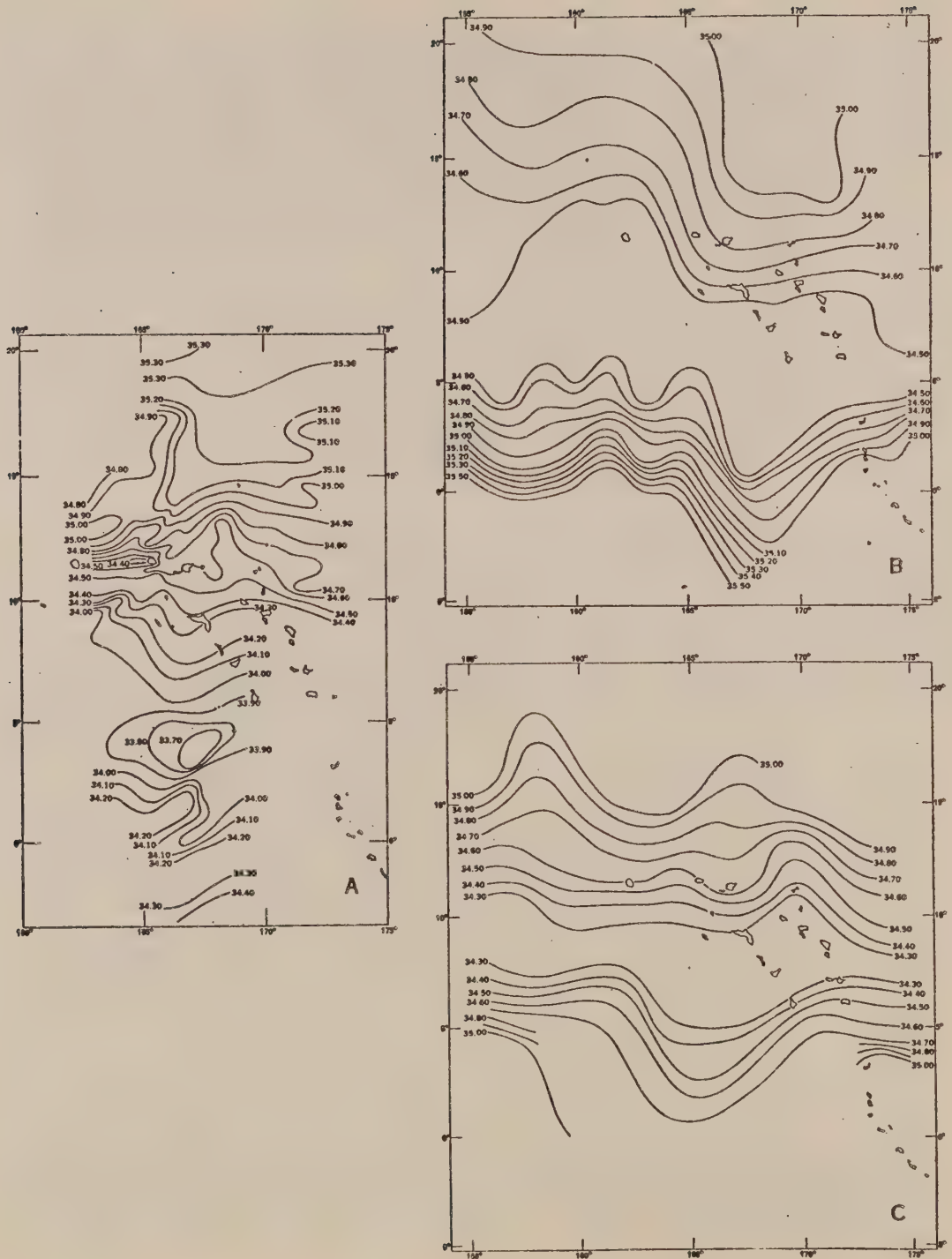


Figure 40.--Horizontal distribution of salinity at surface. A. From Crossroads data, March to August 1946. B. From Japanese data, 1933-41, summer season. C. From Japanese data, 1933-41, winter season (Mao and Yoshida, 1955).

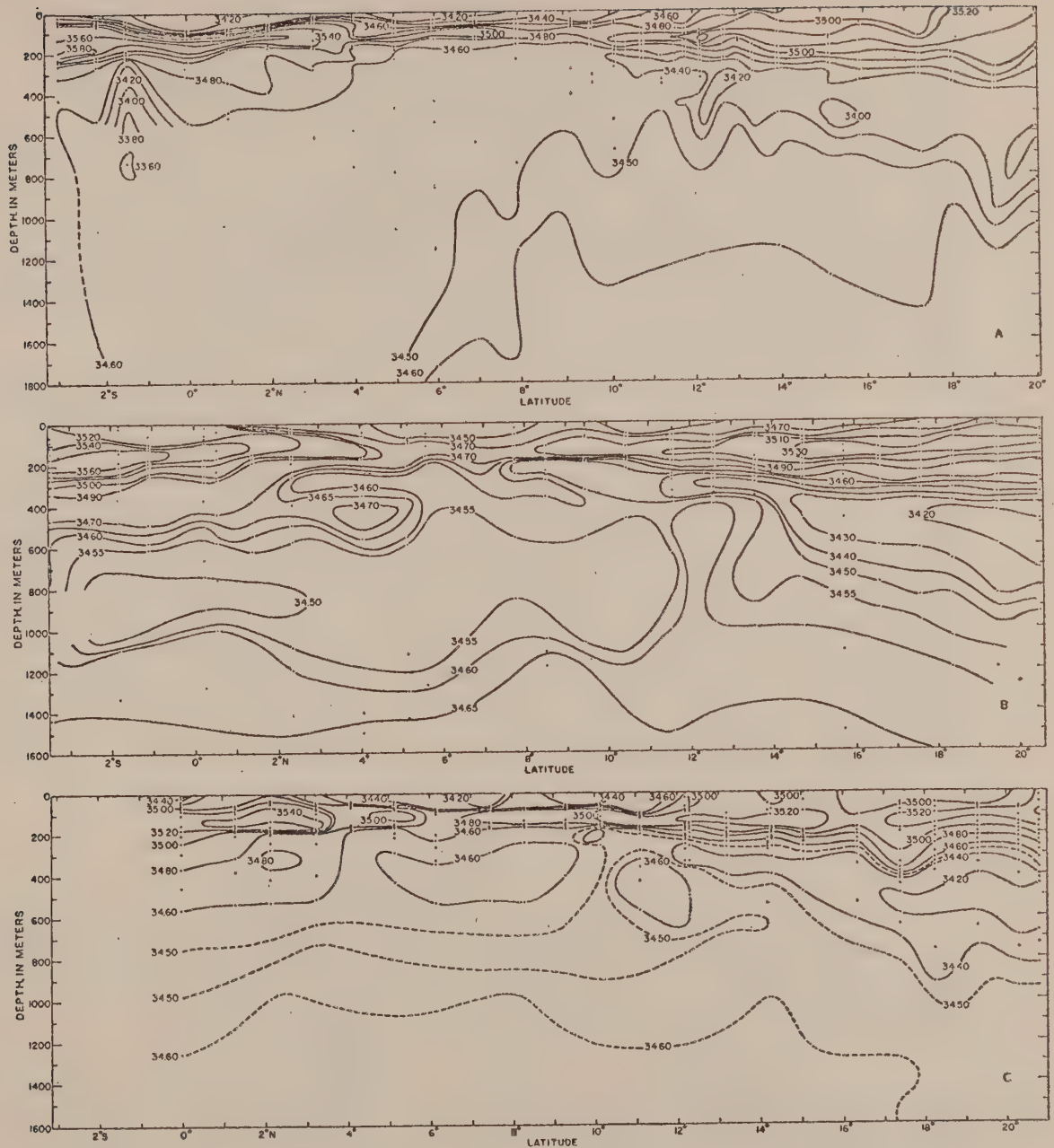


Figure 41.--Vertical distribution of salinity. A. From Crossroads data, March to August 1946. B. From Japanese data, 1933-41, summer season. C. From Japanese data, 1933-41, winter season (Mao and Yoshida, 1955).

In contrast to tropical waters, intermediate waters have low temperature and low salinity, properties which were acquired at the north and south subpolar areas where the air temperature is low and the precipitation high (Mao and Yoshida, 1955). Although of low salinity, intermediate water is dense because of its low temperature. Near the equator, the salinity minimum of about 34.50‰ may be as deep as 2,625 to 3,280 ft (800 to 1,000 m). Of interest is the inclination of the northern intermediate water, which lies at 1,640-1,970 ft (500-600 m) at lat. 20°N but rises almost linearly to 490-655 ft (150-200 m) at lat. 8°-10°N. The ascent of the northern intermediate water with decreasing latitude is probably the result of warming of this water mass through mixing with the surrounding water masses.

The vertical and horizontal distributions of oxygen in waters around Micronesia are depicted in Figures 39 and 42. In the Western Carolines, Masuzawa (1967) found that there is an outstanding oxygen minimum of less than 1.5 ml/liter below the thermocline extending from the coast of Japan southward to lat. 3°N (Figure 39). The core of the minimum changes depth in the vicinity of lat. 15°N. In the Marshalls, Mao and Yoshida (1955) found that the main feature of oxygen distribution is the division of the vertical distribution of oxygen into an oxygen-saturated layer at or near the surface, an oxygen-minimum layer at the intermediate depth, and an oxygen-rich layer at greater depth (Figure 43). A subsurface layer of oxygen supersaturation was also detected in the data, and Mao and Yoshida believed that this feature was probably the result of either the intrusion of the northern tropical water mass or high production of oxygen by plants, or both.

PLANKTON

Zooplankton volume in the Pacific Ocean is distributed in the same manner as $\text{PO}_4\text{-P}$ (Reid, 1962). In general, the volumes are high in the eastern boundary currents, low in central water, relatively high along the equator and in two zones north and south of the equator corresponding to the equatorial divergence (Figure 44).

The distribution of plankton in the western Pacific also has been analyzed and discussed by Vinogradov (1968). Figure 45 shows the stations from which quantitative samples of plankton were collected in the Indian Ocean and western Pacific. Quantitatively, Vinogradov found that the tropical region of the ocean is much poorer in surface plankton than subpolar waters.

In central water, the planktonic biomass from the surface to 328 ft (100 m) is usually less than 25 mg/m³ or roughly 10-20 times less than in subpolar regions. In the equatorial currents, Vinogradov estimated that the planktonic biomass reaches 50-100 mg/m³.

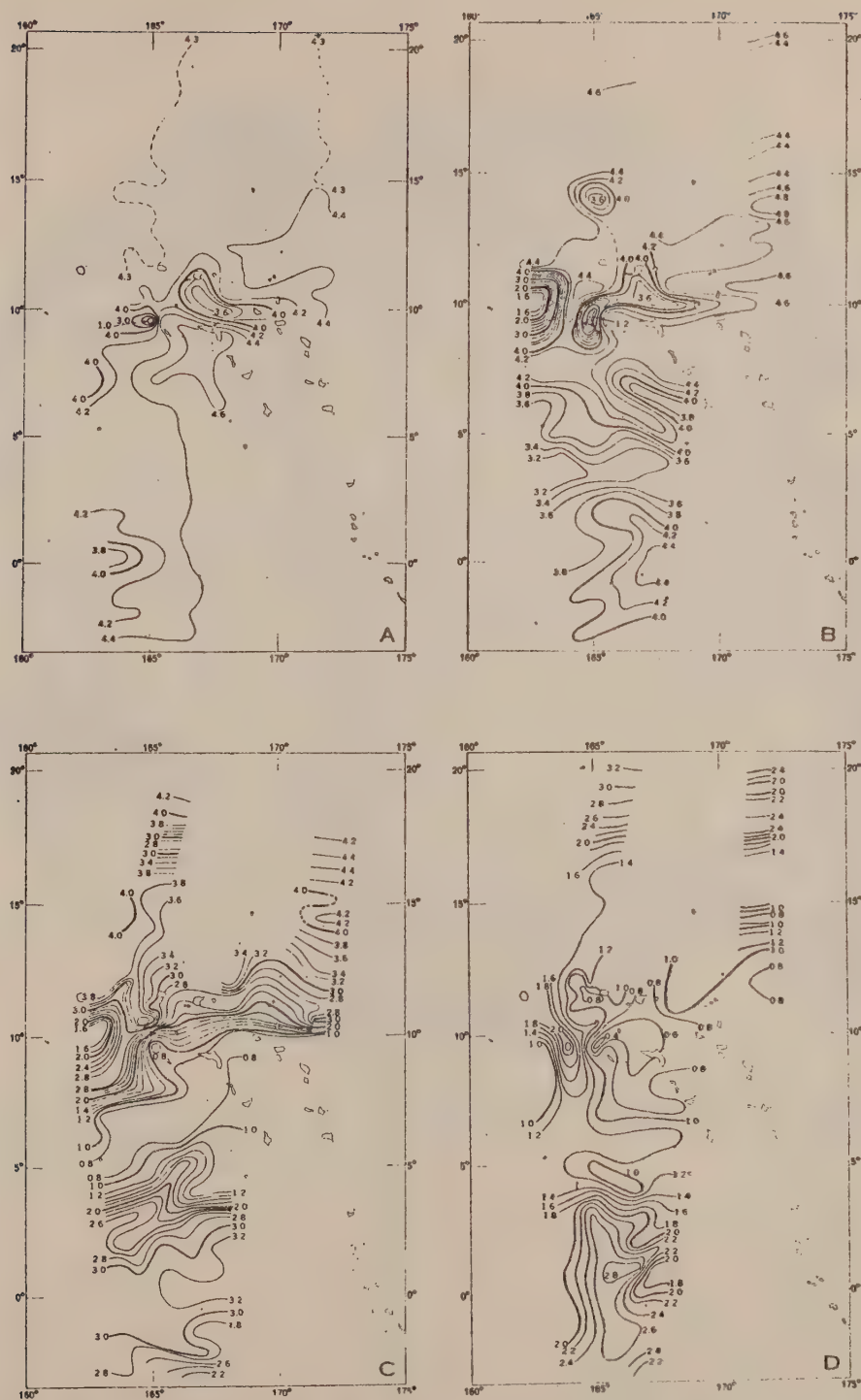


Figure 42.--Horizontal distribution of oxygen concentration (ml/liter), from Crossroads data, March to August 1946. A. At surface. B. At 100 m. C. At 250 m. D. At 500 m. (Mao and Yoshida, 1955).



Figure 43.--Vertical distribution of oxygen concentration (ml/liter). A. From Crossroads data, March to August 1946. B. From Japanese data, 1933-41, summer season (Map and Yoshida, 1955).



Figure 44.--Distribution of zooplankton volume (parts per 10^9 by volume) in approximately the upper 150 m of the Pacific Ocean, shaded by values (Reid, 1962).

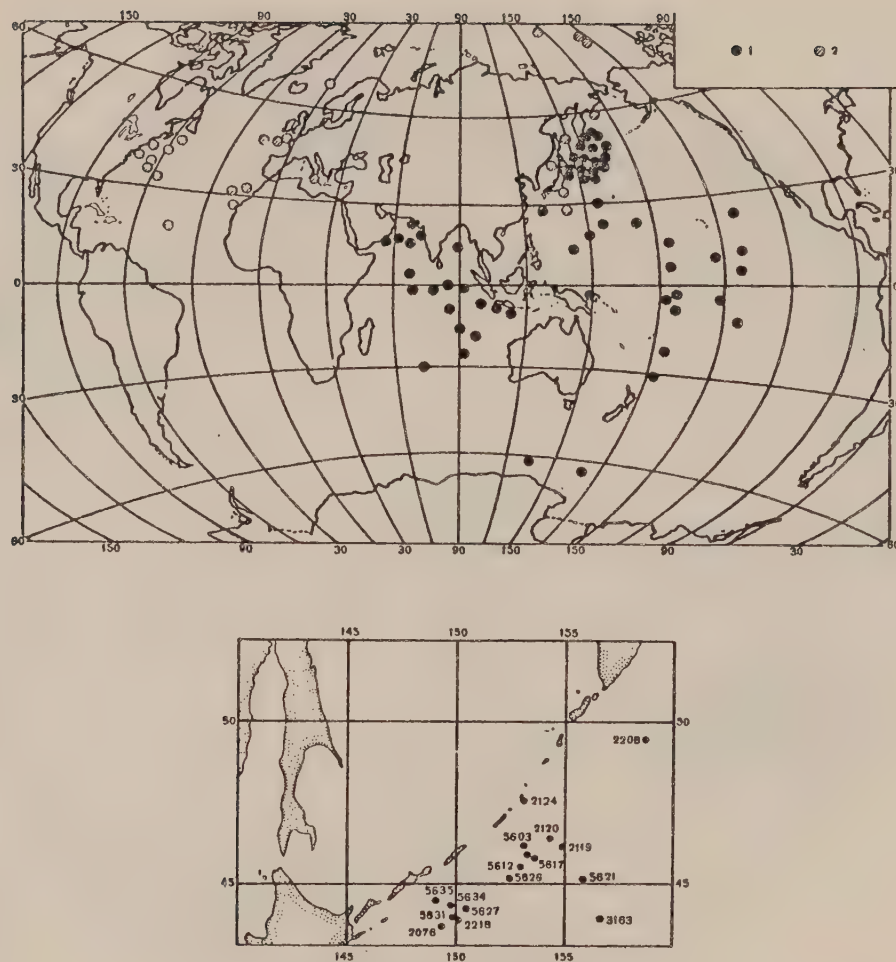


Figure 45.--Stations at which quantitative samples of plankton were taken from the different layers from the surface to a depth of more than 2,000 m. Stations of the Vityaz and Ob (1); stations of other vessels (2) (Vinogradov, 1968).

Four stations were occupied by the Vityaz within or near Micronesia. At a station to the east of the Marianas located in western central water at lat. $19^{\circ}49'N$ and long. $154^{\circ}02'E$, the biomass was 18 mg/m^3 at 0-1,640 ft (0-500 m) (Vinogradov, 1968). Further east at the same latitude and roughly 8° north of the Marshalls or about long. $172^{\circ}E$, Vinogradov found the plankton-poorest area of the tropical part of the northern hemisphere with only 9.0 mg/m^3 at 0-1,640 ft (0-500 m). Water of the northern periphery of the North Equatorial Current in the vicinity of Guam at lat. 11° - $14^{\circ}N$ and long. 142° - $147^{\circ}E$ was also very poor in surface plankton with biomass of only about 8-11 mg/m^3 at 0-1,640 ft (0-500 m).

FISHERIES DEVELOPMENT

The harvesting of the tuna resources in Micronesian waters has a long and varied history. It is of interest, therefore, to discuss some of the developments that took place prior to World War II in the Trust Territory (then the Japanese Mandated Islands) and then review the important developments in the postwar era.

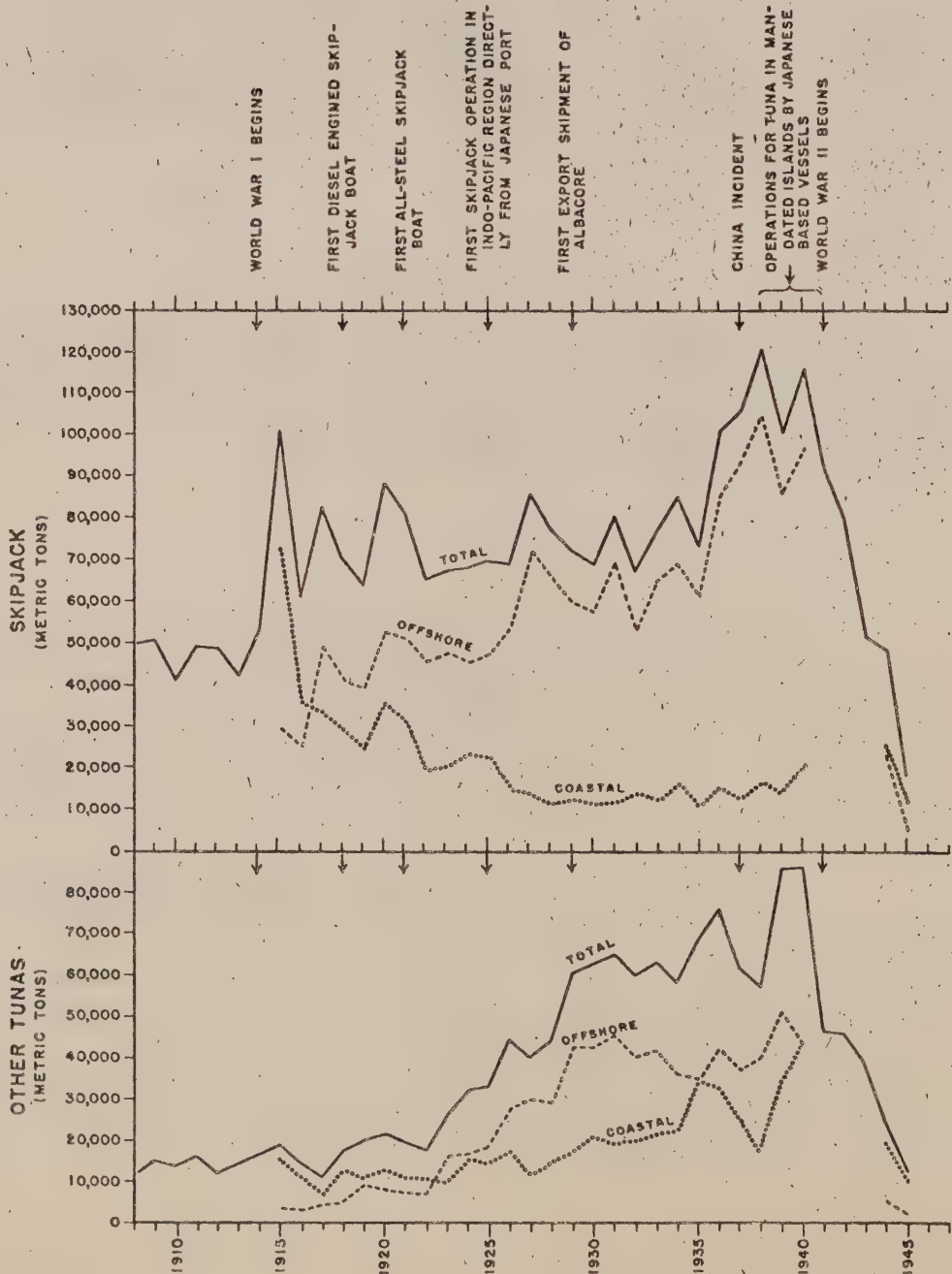
PRE-WORLD WAR II PERIOD

The development of the fisheries potential of Micronesia goes back to the Japanese regime that followed the Spanish and German administrations. After World War I, Japan took possession of the islands under the Treaty of Versailles and was given the mandate to administer all the former German possessions north of the equator. Japanese Civil Administration of the former mandated islands began on 1 April 1922. In 1935, Japan withdrew from the League of Nations and promptly annexed the islands.

Japan was keenly aware of the developmental potential of the fishery resources of the mandated islands. The decade 1921-30 was one of general inquiry into the potential of the marine resources of the numerous islands and atolls. Fishery research and exploratory fishing in 1925-29 showed that many islands possessed tremendous possibilities of becoming bases for large commercial fishing operations (South Seas Government-General Fisheries Experiment Station, 1937b). That the Japanese accurately appraised the tuna fishing potential of the mandated islands is attested to by the rise in the offshore landings of skipjack and other tunas by Japanese vessels (Figure 46).

TUNAS LANDED AT JAPANESE HOME PORTS, 1908-45

Data from Statistical Yearbooks, Ministry of Commerce and Agriculture (1908-15) and Ministry of Agriculture and Forestry (1916-45). Republished in Natural Resources Section Report No.95.



NATURAL RESOURCES SECTION OHQ SCAP

Figure 46.--Tunas landed at Japanese home ports, 1908-45 (Shapiro, 1948).

The Pole-and-Line Skipjack Tuna Fishery

The Japanese skipjack tuna fishery in the former mandated islands developed only after a lengthy period of persistent effort (Cleaver and Shimada, 1950). Even with government subsidies, the fishermen's early efforts failed. But gradually, suitable methods of catching and handling bait evolved.

Because of the scarcity of suitable live bait in many of the island outposts, the Japanese fishermen resorted to using as live bait a wide variety of reef fishes belonging to several families in addition to the anchovies and herringlike fishes (Cleaver and Shimada, 1950). Table 15 lists fishes that were used as live bait in waters of the mandated islands. According to Cleaver and Shimada, "fool bait," Spratelloides delicatulus, was preferred at Saipan and Tinian, but young carangids; filefish, Monacanthus sp.; atherinids; and Caesio sp. were also caught near the reefs and used. Ikebe and Matsumoto (1938), who published a detailed account of their bait investigation in Saipan waters, concluded that in September-November there were no suitable live bait for skipjack tuna fishing. In June-August, large schools of "tarekuchi," Stolephorus heterolobus, and "akamuro," Caesio chrysozonus, were seen but their occurrence was very irregular. The best bait in Palau was the anchovy, S. heterolobus, but during periods of bait shortage, numerous other small fishes were also used (South Seas Government-General Fisheries Experiment Station, 1937b). Ikebe and Matsumoto (1937) reported finding an abundant supply of "tarekuchi" in Yap Bay. At Ponape, fishermen used juvenile Priacanthus sp. and Decapterus sp. (South Seas Government-General Fisheries Experiment Station, 1937a), whereas at Truk, both juvenile Priacanthus and anchovy, Anchoviella purpurea were the best bait.

In fishing for bait, lights were particularly effective in Palau when used with a lift net (Cleaver and Shimada, 1950). At Tinian, a variation of the lift net was used. The fishing vessel anchored near a cliff and the crew, after setting the net, swam along the cliff, rounded up a school of "fool bait," and herded it into the net. To capture reef fish for bait, the Okinawan drive-in net (oikomi-ami) was used. The net, consisting of a large pocket flanked by wings of netting, was set in an open space between the reefs. The crew swam in a large semicircle and herded the various species of reef fishes into the net opening.

The Japanese initially attempted pole-and-line fishing for skipjack tuna near Saipan, but bait was inadequate and the results were poor. Further exploration revealed, however, that the Palau Islands had a large, reliable supply of bait and the Japanese devoted much attention to developing this area (South Seas Government-General Fisheries Experiment Station, 1937b; Smith, 1947). Favorable reports

Table 15.--Some baitfishes used by the Japanese skipjack tuna fishery (Cleaver and Shimada, 1950).

JAPAN AND RYUKYU ISLANDS			
Scientific Name	Common Names	Scientific Name	Common Names
<i>Ama notata</i>	kuroboshi-tenjikudai, ufumi	<i>Harengula zunasi</i>	sappa
<i>Ama truncata</i>	ufumi	<i>Lutjanus vaigiensis</i>	mochinogwa, okifuefuki
<i>Atherina bleakeri</i>	tōgoro-iwashi	<i>Pomacentrus anabotoids</i>	hichigwa, hikigwa
<i>Atherina lauruga</i>	acharara, gin-iso-iwashi	<i>Pseudupeneus</i> sp.	himeji
<i>Beryx decadactylus</i>	gasegasa, nanyō-kiamedai	<i>Sardinella mizun</i>	mizun
<i>Caesio cedralaureus</i>	saneera, shimamuro-gurukun	<i>Sardinia imaculata</i>	boshinashi-iwashi, shiira
<i>Caesio digramma</i>	gurukun	<i>Sardinia melanosticta</i>	ma-iwashi
<i>Caranx faddeba</i>	gatsun	<i>Scomber japonicus</i>	Sabonoko, saba
<i>Engraulis japonicus</i>	katakuchi-iwashi, segurō-iwashi, tarekuchi-iwashi		
SOUTH SEAS			
<i>Ama</i> sp.	akadono	<i>Harengula mollucensis</i>	ma-iwashi, nanyō-ma-iwashi
<i>Aporon</i> sp.	akadono	<i>Labracollosa argenteivestris</i>	tsake
<i>Archamia bleakeri</i>	atohiki-tenjikudai	<i>Mullus</i> sp.	ojisan
<i>Atherina</i> sp.	kokora, tobi-iwashi, tōgoro-iwashi	<i>Sardinella leiogaster</i>	mangurōbu-iwashi
<i>Atherina valenciennesii</i>	nanyō-tōgoro-iwashi	<i>Scomber kamaurta</i>	saba
<i>Caesio chrysozonus</i>	akamuro, gurukun, saneera, umiro	<i>Sphyræna obtusata</i>	kaneau
<i>Caranx leptolepis</i>	aji	<i>Spratelloides delionulius</i>	so-iwashi, baka, nanyō-kibinago, shiira
<i>Caranx malibellus</i>	shima-aji	<i>Trachurus crumenophthalmus</i>	ma-aji
<i>Caranx</i> sp.	aji, gatsun	<i>Trachurus japonicus</i>	ma-aji
<i>Chlidipterus</i> sp.	akadono	<i>Upeneus</i> sp.	ojisan
<i>Dascyllus trimaculatus</i>	montaki	<i>Upeneus tragula</i>	yonehimeji
<i>Decapterus russelli</i>	akamuro	<i>Upeneoides</i> sp.	ojisan
<i>Decapterus</i> sp.	muro, shima-muro	<i>Stolephorus heterolobus</i>	nanyō-katakuchi-iwashi, tarekuchi
<i>Gazza equuleformis</i>	hiiragi	<i>Stolephorus japonicus</i>	bakasako, kibiko-iwashi, sururu

1/ The bait species listed herein were not limited in use exclusively to the area for which listed. They were used by the fishery wherever available in quantity.

Note: The data was obtained from: Prog. Rept. Okinawa Pref. Fish. Exp. St. for 1937; Murakami, H., South Sea Fisheries 5 (5), 1939; and Dr. Y. Hiyaama, Tokyo University, Tokyo, Japan.

Table 16.--Skipjack tuna stick (katsuobushi) production in Japan, Formosa, and the mandated islands, 1922-40, in metric tons (Shapiro, 1948).

Year	Japan	Formosa	Mandated Islands
1922	10,296.5	618.2	0.1
1923	10,600.1	823.1	ND
1924	9,619.1	589.2	1.1
1925	9,958.9	606.5	1.6
1926	9,654.0	556.1	9.9
1927	9,007.5	460.9	4.7
1928	9,514.2	583.0	15.9
1929	9,553.0	611.6	104.3
1930	7,405.2	383.9	279.1
1931	10,613.6	294.7	842.2
1932	8,900.5	142.3	972.9
1933	9,649.7	223.6	1,305.3
1934	11,561.4	338.2	1,695.4
1935	9,031.4	179.0	2,097.4
1936	12,758.0	220.9	2,422.9
1937	9,055.8	185.1	5,812.7
1938	7,767.8	43.6	2,501.2
1939	9,789.9	74.4	3,229.6
1940	10,022.0	ND	2,973.2

a/ Dried weight. This is 17-18 percent of original fresh weight.

ND: No data available

SOURCE: Data compiled from Statistical Yearbooks of Agriculture and Forestry, published by Ministry of Agriculture and Forestry, and Yamamoto, 1942.

regarding the abundance of skipjack tuna schools and the ease of fishing in calm tropical waters throughout the year reached Japan and induced various Japanese fishing companies to establish bases in the mandated islands (Shapiro, 1948). The Japanese Government not only sent Japanese fishermen to these far-flung bases but also provided subsidies to Okinawan fishermen to induce them to migrate to the mandated islands (South Seas Government-General Fisheries Experiment Station, 1937b).

From about 1930, the Japanese established shore-based operations consisting of fleets of small pole-and-line fishing vessels (Smith, 1947). Fishing operations, originally centered around Saipan in the Marianas and at Palau and Truk in the Carolines, were extended to Yap, Ponape, and Kusaie, also in the Carolines, and to Jaluit in the Marshalls (Figure 47) (Ikebe and Matsumoto, 1937). The long distances of these fishing bases from the Japanese homeland precluded the transport of raw fish. As a result, all the skipjack tuna caught were processed for export in the form of dried skipjack tuna sticks called "katsuobushi" (Table 16).

The burgeoning pole-and-line fishery, however, was not without problems. Catches fluctuated widely. Inanami (1941, 1942) observed that in 1939 oceanographic conditions were abnormal over a wide expanse of ocean from the vicinity of Palau eastward to about long. 150°E in January-March. During this period, longline catches of yellowfin tuna declined, whereas the catches of bigeye tuna, Thunnus obesus, and albacore, T. alalunga, increased. The pole-and-line fishing fleet at Palau, Truk and Ponape also experienced poor fishing. The increase in catches of bigeye tuna and albacore meant low-water temperatures in the surface layers; the low-surface temperature also affected skipjack tuna distribution. By May, when oceanographic conditions returned to normal, Inanami found that skipjack tuna fishing improved at Palau, Truk, and Ponape. He concluded that the poor fishing resulting from adverse oceanographic conditions in the countercurrent at about long. 150°E was temporary and that good fishing returned when the conditions returned to normal.

The rapidity with which the skipjack tuna fishery expanded in the mandated islands from 1922 to 1940 is reflected in the catches given in Table 17. Maximum fishing intensity was reached in 1937 when the catch from the mandated islands reached 36,442 short tons (ST) (33,060 metric tons (MT)). The fleet in Palau landed 42% of the total catch whereas that based at Truk produced 38%. The large 1937 catch resulted from the operation of an unusually large number of fishing vessels (Table 18). The fleet was reduced in 1938 because of protests from Japanese producers and subsequent government restrictions on the number of vessels that could be operated in the mandated islands (Smith, 1947). Table 19 shows that by 1940 the fleet was reduced to 132 pole-and-line vessels operating in the mandated islands.

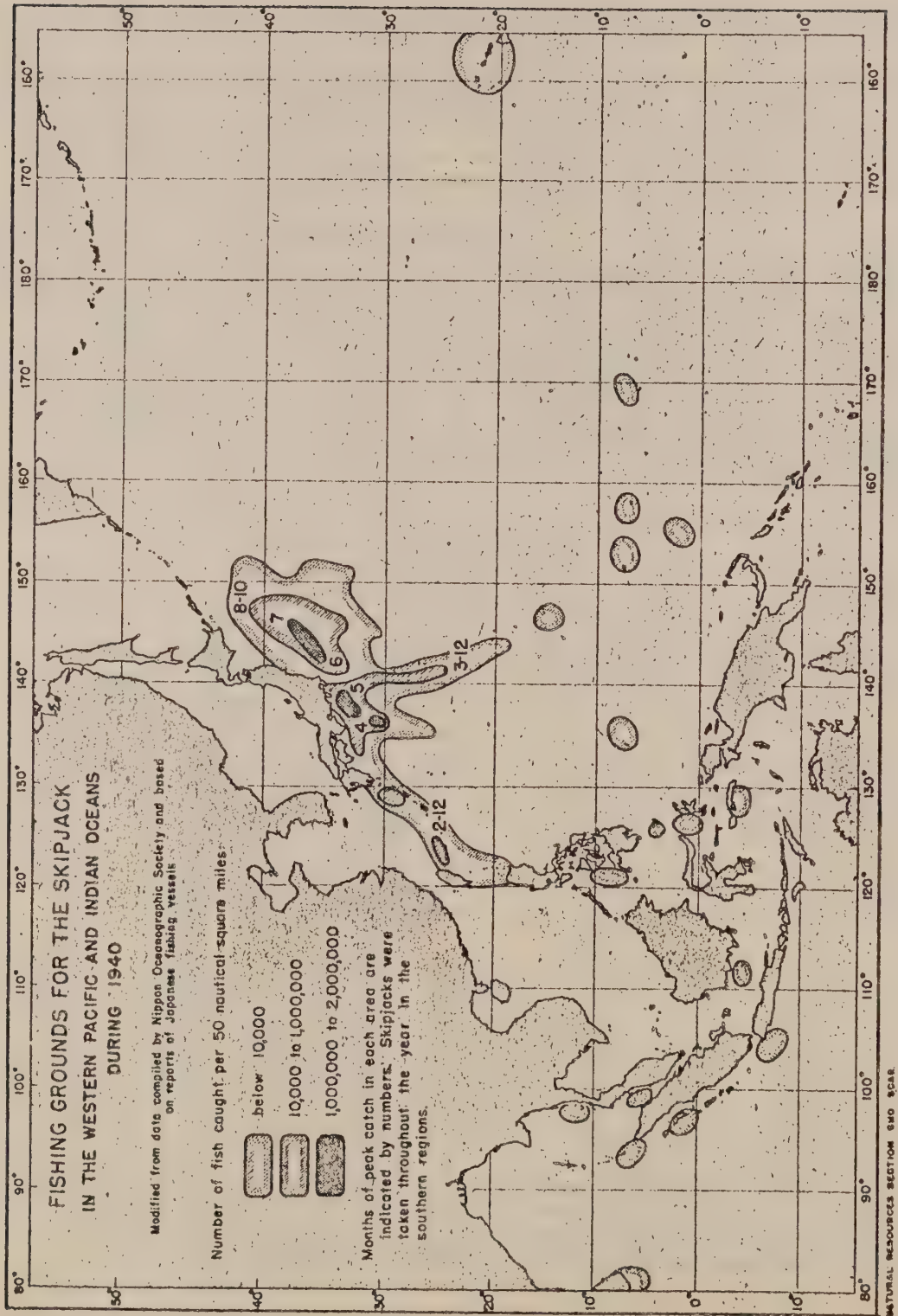


Figure 47.--Fishing grounds for the skipjack tuna in the western Pacific and Indian Oceans during 1940 (Shapiro, 1948).

Table 17.--Skipjack tuna catch landed in the former Japanese Mandated Islands, 1922-40, in metric tons (Shapiro, 1948).

Year	Saipan	Yap	Palau	Truk	Ponape	Jaluit	Total
1922	2.36	ND	ND	3.60	3.75	ND	9.71
1923	2.81	1.46	ND	3.04	ND	ND	7.31
1924	9.10	1.76	1.56	5.21	0.11	ND	17.74
1925	14.81	1.99	8.53	6.05	1.95	ND	36.33
1926	44.84	2.16	42.41	2.76	0.11	ND	92.28
1927	28.11	0.73	14.77	7.50	1.62	0.22	52.95
1928	26.49	1.13	131.45	4.50	0.15	ND	163.72
1929	24.69	0.89	228.90	214.50	0.53	ND	469.51
1930	258.00	0.90	157.06	913.39	6.38	ND	1,335.73
1931	564.26	0.44	548.12	1,097.13	525.24	31.26	2,816.45
1932	1,309.73	ND	1,592.33	810.26	541.18	614.76	4,861.26
1933	1,762.30	ND	2,144.46	1,883.36	928.85	172.43	6,889.40
1934	2,516.00	4.19	3,778.65	1,199.98	1,202.46	255.13	8,956.41
1935	1,785.98	ND	5,390.99	3,002.43	1,313.12	229.78	11,722.30
1936	1,696.01	ND	3,835.97	5,870.23	2,695.84	167.73	14,265.78
1937	2,697.30	ND	13,774.70	12,433.53	4,063.96	91.30	33,060.79
1938	2,392.03	149.28	3,420.21	5,294.78	1,495.58	6.71	12,758.59
1939	2,086.99	36.06	3,548.77	7,639.63	3,707.75	ND	17,019.20
1940	3,379.05	3.64	6,047.38	7,217.09	1,586.30	0.51	18,233.97

ND: No data available

SOURCE: Statistical Yearbook of South Sea Islands published by South Sea Government General.

Table 18.--Number of fishing vessels in the mandated islands, 1937 (Smith, 1947).

Port	Below 20 tons	Above 20 tons	Total	No. crew
Saipan	34	3	37	630
Yap	4	--	4	96
Palau	89	160	249	3,154
Truk	47	3	50	817
Ponape	18	1	19	586
Jaluit	1	--	1	21
Total	193	167	360	5,304

Table 19.--Tuna operations by vessels based in the southwest Pacific, 1940 (Shapiro, 1948).

Base	Type of Operation	Vessels Operated	Fishing Grounds	Amount of Catch	Disposition of Catch
Philippine Islands					
Zamboanga	Pole and line fishing; live bait fishing	20-ton boats - 2 50-ton boats - 2	Within 20 sea miles of port	462 MT (80% skipjack, 20% yellowfin tuna)	Mostly canned or frozen for shipment to U.S.A.
Davao	Pole and line fishing; live bait fishing; tuna long line	Skipjack boats - 5 Tuna long line boats - 6 (tonnage not available)	Within Davao Bay	Only value of catch given: Skipjack - 80,000 pesos Other tunas ^{a/} - 70,000 pesos	Mostly distributed for local consumption
North Borneo					
Tawau	Pole and line fishing; live bait fishing	20-ton boats - 5	Within 20 sea miles of Banga and Shanil	4,643 MT skipjack and yellowfin tuna (1939)	Local distribution; part of skipjack catch processed into fish stick and shipped to Japan
Celebes					
Bontol	Pole and line fishing; live bait fishing	20-ton boats - 10	Within 10 sea miles of Bontol and Ternate	900,000 fish (skipjack and yellowfin tuna); weight not given	Mostly processed into fish stick and shipped to Japan
Amboine	Pole and line fishing; live bait fishing	20-ton boats - 3	Within 10 sea miles of port	350,000 fish (skipjack and yellowfin tuna); weight not given	Local distribution
Mandated Islands					
	Pole and line fishing; tuna long line; live bait fishing		Within 30 sea miles of port		Skipjack mostly processed into fish stick and shipped to Japan
Saipan		Skipjack boats ^{b/} - 25 Tuna long line boats ^{d/} - 2		(metric ton) Skipjack - 1,179.1 ^{c/} Other tunas ^{a/} - 84.5	
Yap		ND		Skipjack - 3.6 Other tunas - 15.8	
Palau		Skipjack boats - 42 Tuna long line boats - 14		Skipjack - 6,047.4 Other tunas - 686.6	
Truk		Skipjack boats - 46 Tuna long line boats - 1		Skipjack - 7,217.1 Other tunas - 46.6	
Ponape		Skipjack boats - 17 Tuna long line boats - 5		Skipjack - 1,566.3 Other tunas - 17.3	
Jaluit		Skipjack boats - 2		Skipjack - 0.5 Other tunas - 8.0	

^{a/} Includes spearfishes^{b/} Skipjack boats operated locally were less than 30 tons^{c/} See Tables 17 and 19 for catch in other years^{d/} Tuna long line boats operated locally were about 40 tons

ND: No data available

SOURCE: Data compiled by Japanese Tuna Fishermen's Association.

The Tuna Longline Fishery

A longline fishery for deep-swimming tunas was also developed in the mandated islands, but not on a scale as large as the skipjack tuna fishery (Shapiro, 1948). In 1931-34, several large Japanese fishing firms began to show increased interest in the deep-swimming tuna resource, and together with several research stations began surveys to determine the fishing grounds and the density of the population (Nakamura, 1951). The surveys covered the area from the mandated islands west through the Dutch East Indies and into the Indian Ocean. The results were encouraging, particularly for the development of longline fisheries for yellowfin tuna, and marlins, Makaira sp. (Ikebe, 1941). The fishing grounds for yellowfin tuna in 1940 are shown in Figure 48.

Lack of capital for the purchase of large, well-equipped fishing vessels and refrigeration equipment contributed to the lack of growth of the fishery and expansion of the fishing grounds (Smith, 1947). Experienced longline fishermen were also in short supply, thus keeping longline operations limited to a few vessels (Table 19) (Shapiro, 1948). By 1938, however, vessel operators in Japan became aware of the potential of the mandated islands fishing grounds for yellowfin tuna and billfishes and began to send large vessels of up to 60 net tons to fish that area. Catches of these large vessels on the fishing grounds around the mandated islands were good (Table 20), with catch per unit of effort higher than those in Japanese waters (lat. 30° to 40°N) and in Ryukyu and Bonin waters (lat. 24° to 30°N) (Tables 21 and 22). The principal species taken was yellowfin tuna followed by sizable quantities of albacore, swordfish, Xiphias gladius, and other billfishes, and small numbers of sharks. Figure 49 shows the fishing grounds for albacore in 1940 in the western Pacific.

Table 23 shows that tuna landings were highest in Palau, which was also the leading port of landing for skipjack tuna. And although fishing could be conducted throughout the year in the calm tropical waters, the catch rates were usually higher in summer during the southwest monsoon season (Table 24).

POST-WORLD WAR II DEVELOPMENTS

In the course of World War II, most of the infrastructure developed by the Japanese in the 1920's and 1930's was destroyed (Nathan Associates, 1966). A postwar survey of the fisheries resources of the former Japanese Mandated Islands was begun as part of the general economic survey undertaken by the Pacific Ocean Division of the United States Commercial Company, Reconstruction Finance Corporation (RFC), at the request of the Navy Department (Smith, 1947).

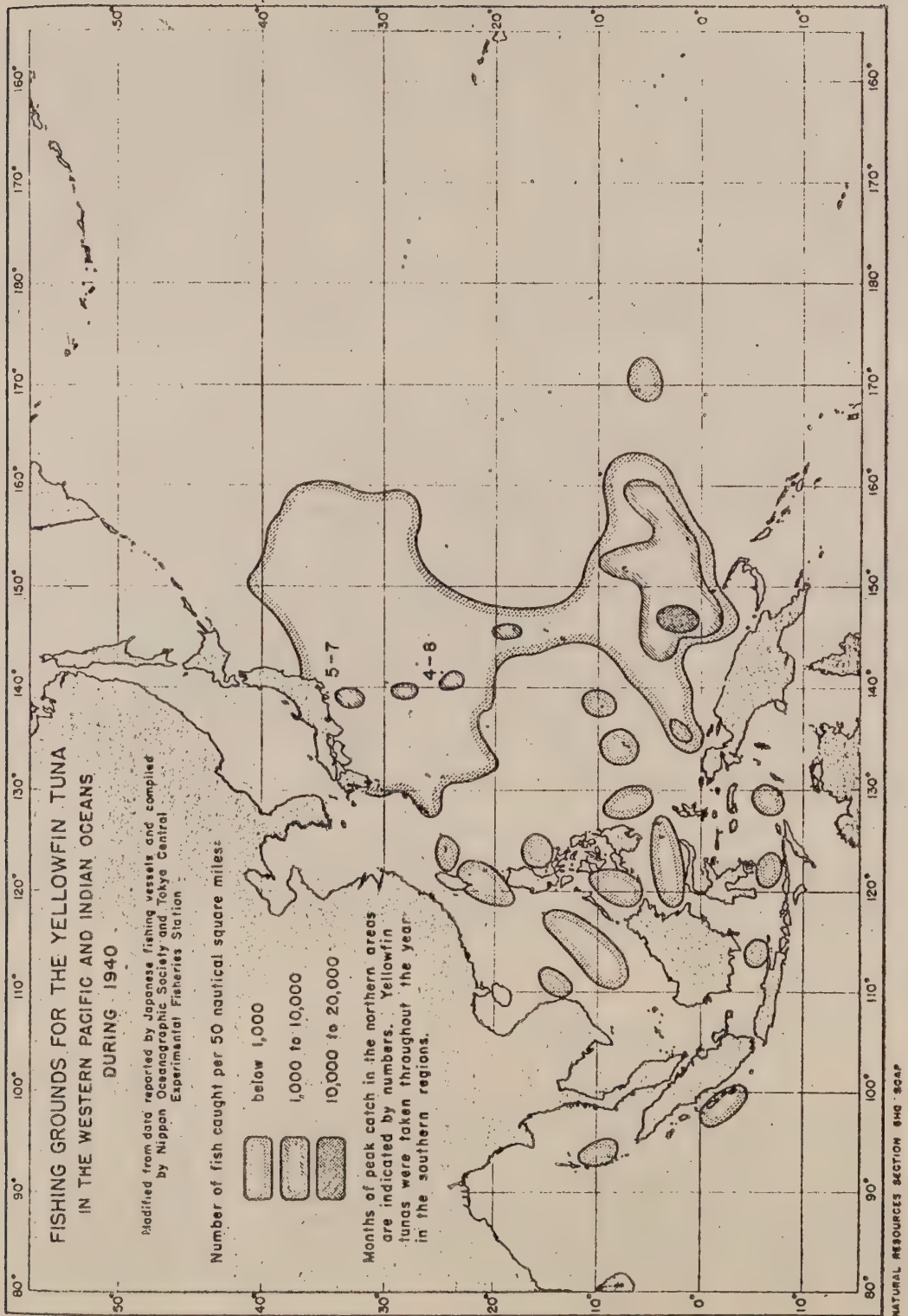


Figure 48.--Fishing grounds for the yellowfin tuna in the western Pacific and Indian Oceans during 1940 (Shapiro, 1948).

Table 20.--Tuna longline catch landed at Misaki Port, 1938-41
(Shapiro, 1948).

Year	Area of operation					
	Japanese waters (lat. 30°-40°N)		Ryukyu and Bonin area (lat. 24°-30°N)		Mandated islands (lat. 0°-24°N)	
	No. of voyages	Total catch (metric tons)	No. of voyages	Total catch (metric tons)	No. of voyages	Total catch (metric tons)
1938	478	4,542	476	7,963	185	5,319
1939	455	4,824	309	5,306	236	5,148
1940	412	5,312	212	2,571	239	8,470
1941	167	1,361	137	2,844	124	5,373

Source: Data compiled by Misaki Tuna Fishermen's Association.

Table 21.--Tuna longline catch in three major fishing areas by vessels operating from the port of Misaki during 1939 (Shapiro, 1948).

Area	No. of voyages	Average fishing days per voyage	Average tonnage per vessel	Total catch (metric tons)	Average catch per fishing day per ton of vessel
Japanese waters (lat. 30°-40°N)	412	15	45	5,312	0.0191
Ryukyu and Bonin area: (lat. 24°-30°N)	212	14	56	2,571	0.0155
Former mandated area: (lat. 0°-24°N)	239	13	113	8,470	0.0241

Table 22.--Composition of tuna catch obtained by longline operations in southwest Pacific and Indo-Pacific regions (Shapiro, 1948).

Area	Number of Hooks Used	Total Catch per 100 Hooks ^a	Percent Composition of Tuna Catch				Avg Weight of Yellowfin Tuna (kilograms)
			Black Tuna	Yellowfin Tuna	Big-Eyed Tuna	Marlins	
East of Formosa: 20°-29°N and 120°-130°E	55,715	1.91	7.3	21.2	8.0	63.5	47.2
East of Philippine Islands to 130°E	10,234	6.35	0.0	56.4	2.3	41.3	33.0
Former Mandated Islands: 0°-12°N and 130°-170°E	220,626	5.23	0.0	79.2	9.3	11.5	33.0
South China Sea off Palawan	110,560	4.65	0.0	90.3	4.5	5.2	ND
Sulu Sea	4,600	3.96	0.0	ND	ND	11.1	47.1
Celebes Sea	157,156	4.37	0.0	ND	ND	16.3	41.0
North of New Guinea and Solomon Islands: from 130° to 160°E	21,792	4.21	0.0	71.8	7.1	21.1	37.0
Banda Sea: southeast and south of Celebes	81,779	8.40	0.0	89.5	3.3	7.2	48.5
Neighboring waters of Timor Island	48,756	9.19	0.0	88.6	3.8	7.6	48.0
Southern coast of Java	20,628	3.89	0.0	67.8	17.4	14.8	49.6
Southern coast of Sumatra	147,428	10.64	0.0	84.7	8.2	7.1	ND
Neighboring waters of Andaman and Nicobar Islands	15,568	6.23	0.0	89.4	4.4	6.2	40.0

^a/ In Japanese waters the total tuna catch per 100 hooks averages between 3 and 4 fish.

ND: No data available

SOURCE: Data obtained by Japanese research and fishing vessels from 1930-40 and compiled by H. Nakamura of the Tokyo Central Fisheries Experimental Station.

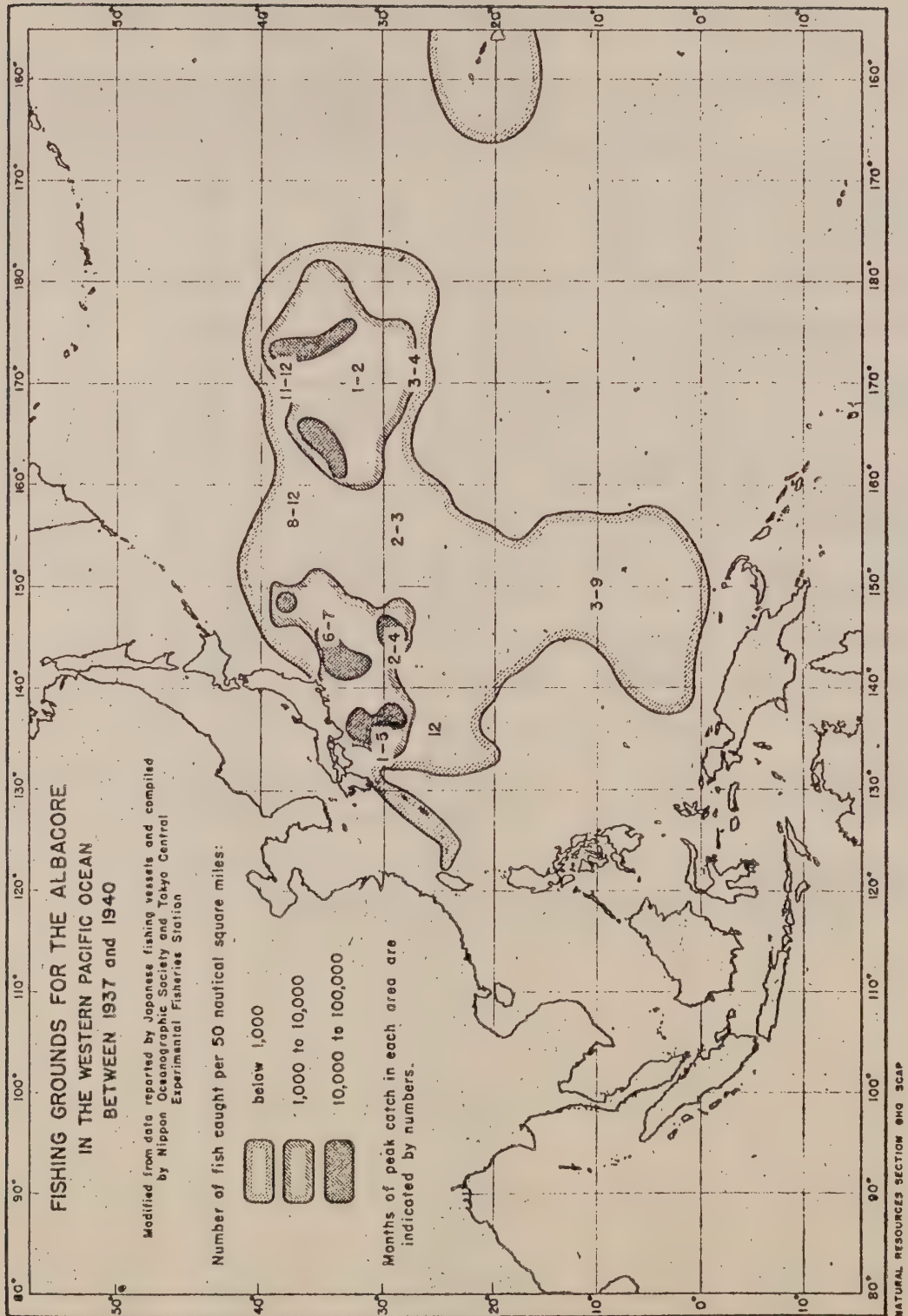


Figure 49.--Fishing grounds for the albacore in the western Pacific Ocean between 1937 and 1940
(Shapiro, 1948).

Table 23.--Tunas, excluding skipjack tuna, landed in the mandated islands, 1922-40, in metric tons (Shapiro, 1948).

Year	Salpan	Yap	Palau	Truk	Ponape	Jalut	Total
1922	1.31	ND	ND	ND	2.36	2.40	6.07
1923	1.25	1.24	ND	ND	1.76	2.40	6.65
1924	1.53	1.54	6.75	ND	0.20	1.34	11.96
1925	1.40	1.43	5.31	EE	2.54	1.50	12.23
1926	2.31	0.75	46.80	0.34	4.50	0.83	55.53
1927	2.91	0.38	41.22	7.14	6.58	3.05	54.28
1928	1.26	1.05	152.33	ND	7.75	1.29	164.18
1929	0.56	0.76	167.94	0.40	1.62	0.22	172.00
1930	4.53	0.77	92.26	8.53	3.54	2.37	112.00
1931	16.73	0.46	156.61	29.43	4.83	3.85	211.91
1932	43.24	ND	137.62	5.18	34.69	135.72	361.45
1933	0.31	ND	242.23	55.39	41.42	25.87	365.22
1934	27.26	7.67	278.88	55.39	26.49	31.36	427.05
1935	42.42	0.73	301.18	98.50	23.50	13.91	480.99
1936	151.02	ND	213.26	173.02	29.96	14.85	587.11
1937	88.82	ND	129.78	342.18	56.37	3.96	681.17
1938	33.94	2.21	73.13	121.44	60.21	ND	270.93
1939	44.38	7.40	184.94	93.62	31.58	5.14	361.54
1940	24.51	15.82	686.57	46.62	17.31	7.97	858.80

a/ Includes spearfishes

ND: No data available

SOURCE: Statistical Yearbook of South Sea Islands, published by South Sea Government General.

Table 24.--Seasonal tuna catch by longline operations in southwest Pacific and Indo-Pacific regions (Shapiro, 1948).

Area	Southwest Monsoon Season (Summer)		Northeast Monsoon Season (Winter)	
	No of Hooks Used	Total Catch per 100 Hooks a/	No of Hooks Used	Total Catch per 100 Hooks a/
East of Formosa to 120°30'E	900	1.78	7,032	2.94
East of Philippine Islands to 130°E	7,840	7.98	2,394	0.67
Former Mandated Islands: 0°-12°N and 130°-170°E	115,099	5.40	105,527	4.18
South China Sea off Palawan	4,156	3.32	106,402	4.69
Celebes Sea	10,493	8.86	146,663	4.06
North of New Guinea and Solomon Islands: from 130° to 160°E	10,500	4.39	11,292	4.04
Banda Sea: southeast and south of Celebes	80,089	8.56	1,650	7.34
Neighboring waters of Timor Island	2,215	6.23	146,546	9.33
Southern coast of Sumatra	300	3.67	147,128	10.72

a/ Includes yellowfin tuna, big-eyed tuna, and marlins.

SOURCE: Data obtained by Japanese research and fishing vessels from 1930-40 and compiled by H. Nakamura of the Tokyo Central Fisheries Experimental Station.

Development of the Palau Skipjack Tuna Fishery

Attempts to revive the skipjack tuna fishery which thrived under the Japanese administration were first started in Saipan in 1946 (Smith, 1947). Two Japanese sampans, sunk at Saipan, were refloated, repaired, and subsequently operated by the U.S. military government. Manned by 26-28 fishermen who were paid only the regular daily wages established by the military government, the sampans caught and distributed the fish free to the native population. This operation, however, was short-lived. Inexperienced crews, inadequate fishing gear and maintenance facilities, and lack of dockside and refrigeration facilities all contributed to the abandonment of the project (Wilson, 1963).

In 1948, the Pacific Exploration Company, operating under contract with the RFC, dispatched two fishing vessels to prospect for tuna in the western Pacific (Smith and Schaefer, 1949). The MV Oregon, equipped for live-bait fishing, was sent to the Marianas and between 15 March and 19 April, fished for bait and scouted for tuna from Guam north to Farallon de Pajaros and back to Guam. Although much time was devoted to prospecting for bait along the beaches and cliffs of all the important islands in the Marianas, very little bait was found. Night-light fishing at Guam, Tinian, Alamegan, Pagan, Maug, and Rota was also tried and 3-5 lb (1.4-6.8 kg) of bait could sometimes be netted under the light but these amounts were hardly sufficient for a vessel the size of the Oregon.

Among the islands, Guam was the best baiting area (Smith and Schaefer, 1949). Night baiting produced 15-20 lb (6.8-9.1 kg) per night at Apra Harbor, Port Nerizo, and Talogogo Bay, whereas day baiting produced similar amounts at places along the cliffs on the leeward coast. The species taken were mixed. Half to three-fourths of the bait caught was round herring, Spratelloides sp., the rest being a small anchovy. Smith and Schaefer (1949) concluded that the supply of live bait, therefore, was uncertain and should be studied further.

Concerning skipjack tuna, Smith and Schaefer (1949) found that there are sufficient quantities of skipjack tuna in the waters around the Marianas to support a commercial fishery. But because of the limited quantities of bait in the Marianas, small boats of limited cruising range were recommended. In 5-6 days of scouting, the Oregon sighted 35 bird flocks and 8 fish schools, 3 of which were identified as skipjack tuna and 1 as yellowfin tuna.

Exploration of the Eastern Carolines and the Marshalls was conducted by MV Alaska. Fitted out as a tuna purse-seiner, Alaska had no need for bait but made cursory examination of beaches throughout the Eastern Carolines and the Marshalls. The results indicated that bait was not abundant. Schools of flat herring, Macrura sp.,

3-5 in (7.6-12.7 cm) long, were seen at Ailinglaplap in the Marshalls and at Truk in the Carolines. Marshall islanders also reported that the Japanese found large amounts of bait at Jaluit in the Marshalls. Reports also indicated that the Japanese found bait at Losap and Satawan, south of Truk.

Because few fish were seen during Alaska's cruise, no attempts were made to set the net. Only six schools were sighted; two in the Marshalls, and four in the Carolines.

Smith and Schaefer (1949) interviewed natives for information and found that January-March were poor tuna-fishing months and that May-August were the best. They concluded that Alaska's exploratory cruise was made at the wrong time of the year. Furthermore, they believed that it might be possible to develop a tuna fishery in the Eastern Carolines and Marshalls, but that it should be limited to late spring and early summer.

In the Western Carolines, Oregon visited Ulithi, Yap, Palau, Pulo Anna, Sonsoral, Tobi, and Helen Reef (Smith and Schaefer, 1949). Bait scouting at Ulithi revealed only a few schools of fish about an inch long. Yap had no bait at all. At Palau, however, bait was plentiful. Schools containing from a few to several hundred scoops were found along much of the rugged shoreline of the many limestone islands. The bait was primarily silverside, Atherinidae, but also caught were flat herring and small round herring. The most important species used by the Japanese was a small translucent anchovy; however, this species was not found by the crew of the Oregon.

Scouting for tuna in Palau waters, Oregon sighted 23 fish schools and about 20 bird flocks (Smith and Schaefer, 1949). Of the 14 schools identified to species, 7 were skipjack tuna, 5 were bigeye tuna, 1 was mixed skipjack-bigeye tunas, and 1 was black skipjack, Euthynnus lineatus. Smith and Schaefer (1949) concluded that a skipjack tuna fishery could be developed in Palau, but they recommend a relatively small vessel for fishing operation because it would have the advantage of moving close to the baiting grounds. A large tuna clipper might be necessary only if fishing was carried on outside the Palaus.

Despite the promising outlook for a commercial fishery for skipjack tuna in Palau, the Trust Territory Government, working with a limited budget, believed that fisheries development should be kept at a level sufficient only to provide food for the Micronesian people. But it became increasingly apparent that the Trust Territory needed to develop its marine resources and the government saw that fishing, traditionally an economic activity of the people of Micronesia, was an important source of jobs and money income.

Preparations for reviving commercial fishing in Palau were started in the mid-1950's and by 1962, a complete dockside fishery station with ice plant, sharp freezer, and storage reefer was in operation (Wilson, 1963).

In 1963, the Trust Territory Government and Van Camp Sea Food Company completed arrangements to begin commercial skipjack tuna fishing in Palau (Rothschild, 1966b). The company constructed a 1,500-ton freezer-storage plant at Malakal Harbor, purchased pole-and-line fishing vessels from Japan and Okinawa, and manned the vessels with skilled Okinawan fishermen and Micronesian trainees. According to terms of the agreement, the trained Micronesians will eventually replace the Okinawans in the fishery. Actual fishing began in the summer of 1964, at which time six skipjack tuna fishing vessels were in operation. Details of the Palau skipjack tuna fishery may be obtained from Wilson (1965) and Uchida (1970).

The pole-and-line fishing vessels in Palau are typical of those used for surface school fishing throughout the western Pacific. They are characterized by a long, high bowsprit with fishing racks extending from the tip of the bowsprit along both sides of the vessel and completely around the stern.

In 1974, there were 11 vessels in the fleet. The vessels ranged in length from 58 to 65 ft (17.7 to 19.8 m) and varied in gross tonnage from 32 to 49 tons. Three of the 11 vessels, operated by Micronesian crews, had 90 hp engines and a maximum speed of 6.5 knots. The remaining vessels, operated by Korean and Okinawan crews, had from 210 to 320 hp engines and cruising speeds of 8 knots. Usually, these vessels carried 18-20 fishermen.

Wilson (1966) reported on the building of a sampan at the Palau Boatbuilding and Drydocking Association. According to Wilson, this vessel, named Emeraech, was almost identical in design with the Hawaiian skipjack tuna sampans, which are noted for seaworthiness, stability, and speed but not carrying capacity. Owned and operated by the Trust Territory Government, Emeraech was about 75 ft (23 m) long, had six baitwells arranged on the afterdeck in two parallel rows of three, and carried about 50 buckets of bait. Characteristic of the Emeraech (and Hawaiian sampans) was the large, clear afterdeck, unlike the Japanese- and Okinawan-designed vessels which have all baitwells, fishholds, and iceholds on the well deck forward of the bridge. The Emeraech also had a sponson or fishing platform, about 4 ft (1.2 m) wide, raised about 2 ft (0.6 m) above deck and extending around both sides of the afterdeck and across the stern. Emeraech had a maximum speed of 11 knots and carried from 10 to 14 crew members.

Development of a pole-and-line fishery depends to a large extent on the abundance of live bait. In the 1920's, the Japanese found bait plentiful everywhere inside the reefs at Palau (South Seas Government-General Fisheries Experiment Station, 1937b). And the Oregon also confirmed the abundance of baitfish along much of the rugged shoreline of the many limestone islands between Peleliu and Koror (Smith and Schaefer, 1949).

In his report, "The bait resources of the Palau Islands" (unpublished),¹ Wilson concluded that the small round herring, locally called "kuaol," Spratelloides delicatulus, was the most important and abundant bait species in Palau during a survey made in November 1956. But Smith and Schaefer (1949) learned that a small, translucent anchovy was the "number-one bait" of the Japanese, with the silverside a close second.

Samples of baitfish collected routinely in the 1960's at Palau by technicians of the Honolulu Laboratory of the National Marine Fisheries Service (formerly Bureau of Commercial Fisheries) indicate that the "number-one bait" is the anchovy, Stolephorus heterolobus, call "katakuchi" by the Okinawan fishermen (Uchida, 1970). Other species present in the bait samples have been identified as silverside, locally called "teber," Allanetta woodwardi, Sardinella sp., and small round herring or "kuaol," S. delicatulus. The present fleet in Palau relies primarily on fishing at night for anchovy, which accounts for about 90% of the bait catch.

The baiting ground in the Palaus, shown in Figure 50, is the limestone islands area, extending from the western entrance to Malakal Harbor southward to the western boat passage by Gamudoko Island (Uchida, 1970). Figure 51 shows the main baiting area in detail. The vessels fish for bait by night light, usually catching sufficient bait by 0400-0500. They depart for the fishing grounds by daybreak and return to port in the evening to unload the day's catch, resupply, and return once again to the baiting ground. In 1964-72, the bait catch varied between 10,888 buckets in 1964 and 111,103 buckets in 1969 and averaged 68,844 buckets (Muller, MS)² (Table 25). Baiting intensity during those years also fluctuated widely, from 270 to 2,860 boat nights. The catch per boat night was 40.3 buckets in 1964, fluctuated irregularly between 44.7 and 49.7 buckets in 1965-68, rose sharply to 69.9 buckets in 1969 then declined precipitously to only 17.0 buckets in 1971. The 1972 catch rate showed a recovery to 45.9 bucket/boat night.

¹Wilson, P. T. [1957] The bait resources of the Palau Islands. Hawaiian Tuna Packers, Ltd., Honolulu, on file at Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812, 21 p. (Mimeogr.)

²Muller, R. G. Some aspects of the population biology of Stolephorus heterolobus from Palau. Draft report distributed for information in connection with Tuna Baitfish Workshop, 4-6 June 1974, Honolulu, HI 96812.

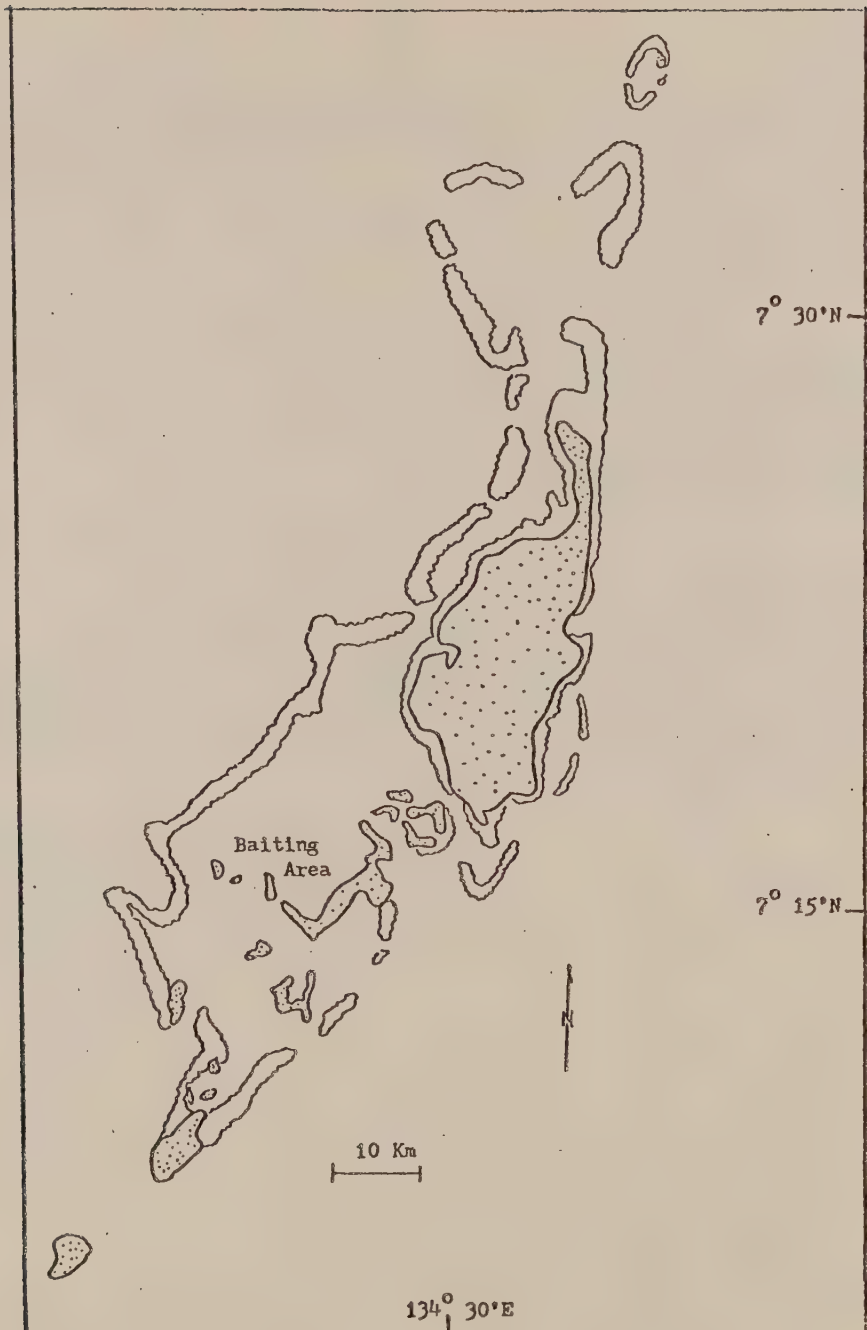


Figure 50.—Baiting area in the Palau Islands (Muller; see text footnote 2).

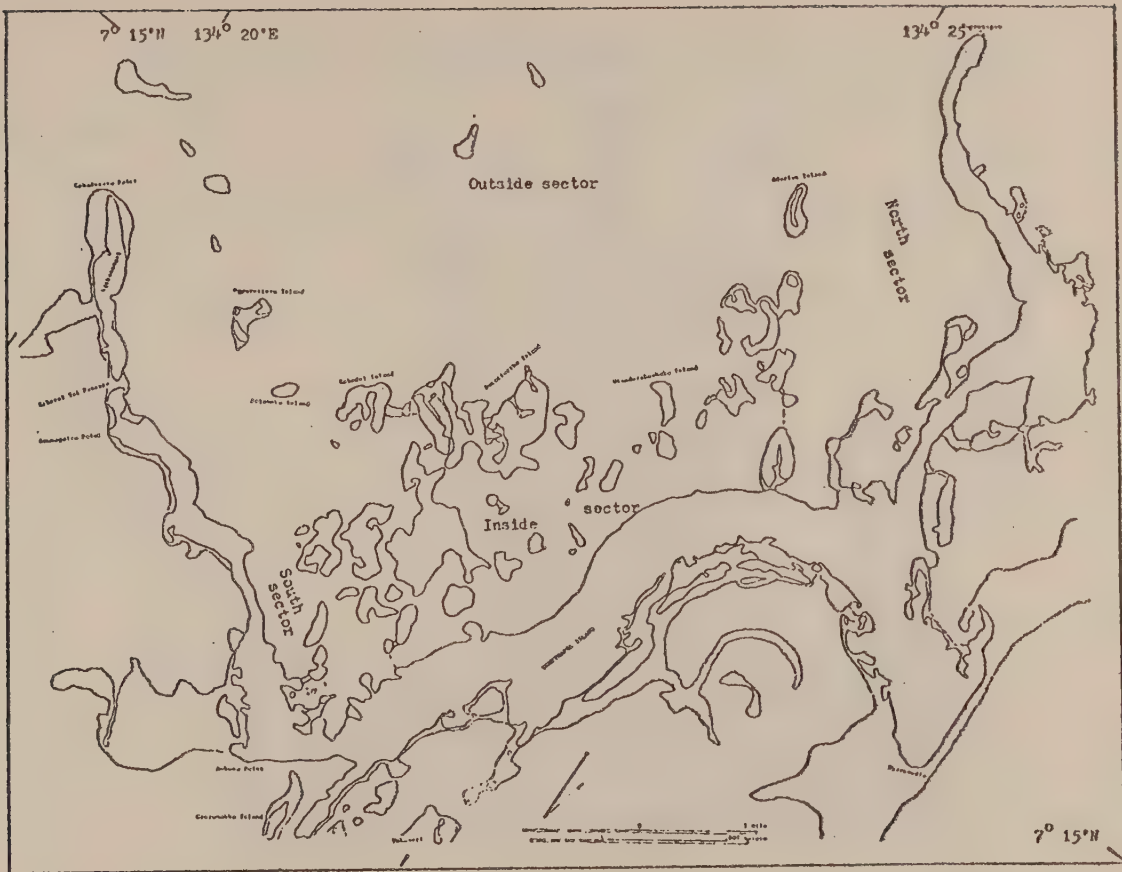
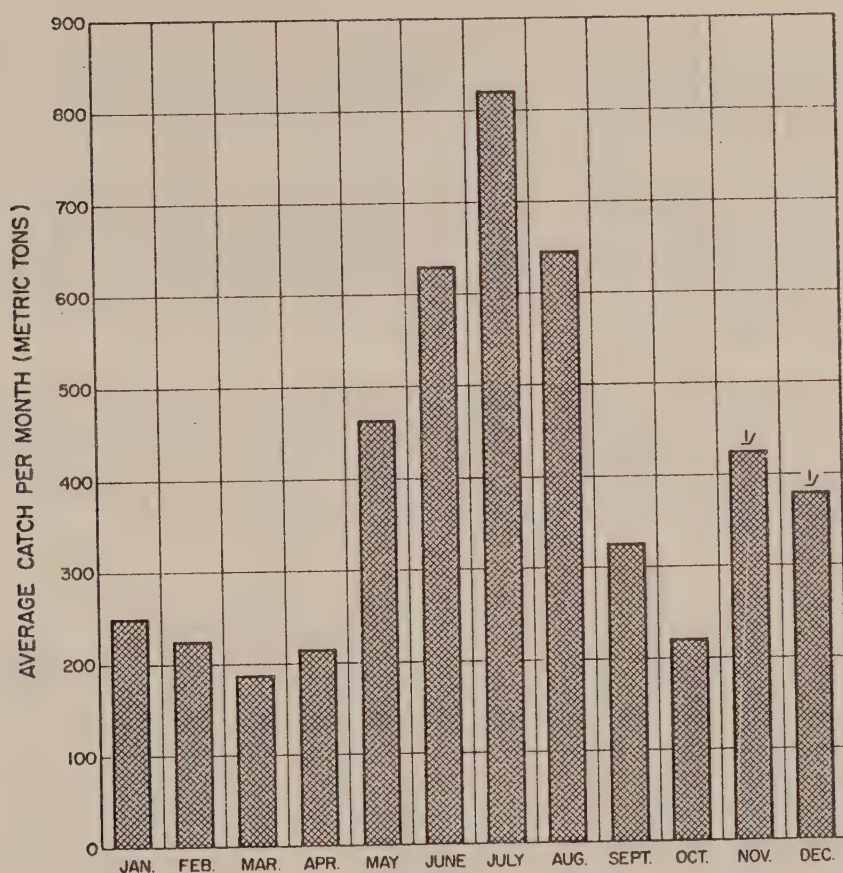


Figure 51.--Detailed map of the main baiting area in the Palau Islands
(Muller, see text footnote 2).

Table 25.--Annual total catch, effort, and catch per effort statistics for the Palauan bait fishery (Muller, see text footnote 2).

Year	Catch buckets	Boat nights	Catch/boat night
1964	10,888	270	40.3
1965	53,358	1,073	49.7
1966	62,780	1,406	44.7
1967	73,620	1,616	45.6
1968	82,082	1,784	46.0
1969	111,103	1,590	69.9
1970	96,462	1,565	61.6
1971	48,674	2,860	17.0
1972	80,630	1,755	45.9



^{1/} Based on data for 1966-70.

Figure 52.--Average monthly catch of skipjack tuna in the Palau fishery 1966-71 (Uchida, in press).

In Palau, year-round fishing for skipjack tuna is possible, although the catches fluctuate widely from month to month. Monthly catches, averaged for the years 1966-71 and shown in Figure 52, peak twice during the year. A major peak appears in July and a minor one in November. The average monthly catch varied from a low of 203 ST (184 MT) in March to 905 ST (821 MT) in July (Congress of Micronesia, 1972). The pre-World War II Japanese fishery also experienced the summer and winter peaks in abundance (Uchida, 1970). The poor fishing in February was associated with generally lower water temperatures at this time of the year due to heavy rains (South Seas Government-General Fisheries Experiment Station, 1937b).

Annually, the catches from the Palau skipjack tuna fishery varied between 3,243 and 9,304 ST (2,942 and 8,441 MT) in 1966-70 (data for 1971 incomplete), and averaged 5,773 ST (5,237 MT) (Table 26). Catches made in Palau in 1966-71 compare favorably with those made by the Japanese in 1922-40 (Table 17).

Japanese Southern Water Pole-and-Line Fishery

The most dramatic increase in fishing effort and catches of skipjack tuna from Trust Territory waters since the end of World War II has been made by the Japanese pole-and-line fishing fleet. The development of Japan's southern water (refers to waters south of lat. 24°N) fishery stems from the realization that the skipjack tuna resource in Japan's coastal waters was nearing the limit of exploitation (Tohoku Regional Fisheries Research Laboratory, undated a). A second prime consideration for expansion southward was that the large available skipjack tuna resource in the southern waters could be exploited during the off-season for skipjack tuna in Japanese coastal waters.

Figure 53 depicts the geographical location of skipjack tuna fisheries and fishing areas in the Pacific in the early 1960's. All the fishing at that time was confined to areas relatively close to the coastlines of Central and South America and Japan and near island groups in the central and western Pacific. From about 1962, Japanese vessels operating out of ports in several prefectures (Kagoshima, Mie, Shizuoka, Ibaraki, and Miyagi) and carrying live anchovies, Engraulis japonica, obtained from bait stations in southern Japan, began to move into southern waters along the Bonin and Mariana archipelagoes (Tohoku Regional Fisheries Research Laboratory, undated b).

The principal fishing grounds in the southern water fishery are divided into the Bonin-Mariana region, which is usually fished in July-October, and the Caroline Islands region fished from November through March (Iwasaki, 1970). The expansion of the fishing grounds, shown in Figure 54, continued over the years so that by 1971 some vessels were fishing in equatorial waters between Truk and the Marshalls and south of the equator in waters from lat. 1°-5°S between long. 147°

Table 26.--Number of boats fishing, catches of skipjack tuna, and catch per boat, by month, in the Palau skipjack tuna fishery, 1966-71 (Congress of Micronesia, 1972).

Month	1966			1967			1968		
	Boats	Catch	Catch per boat	Boats	Catch	Catch per boat	Boats	Catch	Catch per boat
	No.	MT	MT	No.	MT	MT	No.	MT	MT
January	--	101.414	--	5	361.103	72.2	10	341.896	34.2
February	--	220.402	--	4	107.918	26.9	9	477.397	53.0
March	--	133.402	--	4	101.678	25.4	8	443.479	55.4
April	--	108.210	--	4	120.516	30.1	6	375.414	62.5
May	--	161.820	--	4	130.399	32.6	6	733.787	122.3
June	--	185.283	--	10	258.949	25.9	11	771.853	70.1
July	--	524.830	--	10	384.659	38.4	11	996.055	90.5
August	--	326.672	--	9	430.843	47.9	9	769.427	85.4
September	--	477.440	--	10	210.327	21.0	9	177.879	19.7
October	8	320.839	40.1	10	205.587	20.6	5	37.497	7.5
November	8	250.227	31.2	10	580.735	58.1	6	84.864	14.1
December	8	130.871	16.3	9	510.787	56.7	4	2.868	0.7
Total	--	2,941.600	--	--	3,403.501	--	--	5,212.416	--
Average	--	245.134	--	7.4	283.625	38.2	7.8	434.368	55.5
	1969			1970			1971		
January	8	72.107	9.0	7	389.421	55.7	6	242.875	40.4
February	9	141.385	15.8	7	274.983	39.2	6	102.734	17.1
March	8	35.330	4.4	6	192.730	32.1	8	199.799	24.9
April	5	58.195	11.6	7	422.949	60.4	7	190.919	27.2
May	5	259.846	51.9	9	1,021.297	113.5	8	466.544	58.3
June	4	623.630	155.9	9	1,642.223	182.4	8	282.685	35.3
July	8	678.585	84.8	9	2,343.803	260.4	12	72.200	6.0
August	9	1,282.252	142.4	9	1,055.522	117.3	12	78.200	6.6
September	9	809.540	89.9	2	95.873	47.9	12	197.877	16.5
October	9	593.678	65.9	5	149.753	29.5	6	31.895	5.3
November	7	702.714	100.4	5	512.560	102.5	--	--	--
December	7	929.011	132.7	6	340.172	56.7	--	--	--
Total	--	6,186.183	--	--	8,441.286	--	--	1,716.832	--
Average	7.3	515.515	70.3	6.75	703.441	104.2	8.5	171.683	20.2

¹Data unavailable at time of publication.

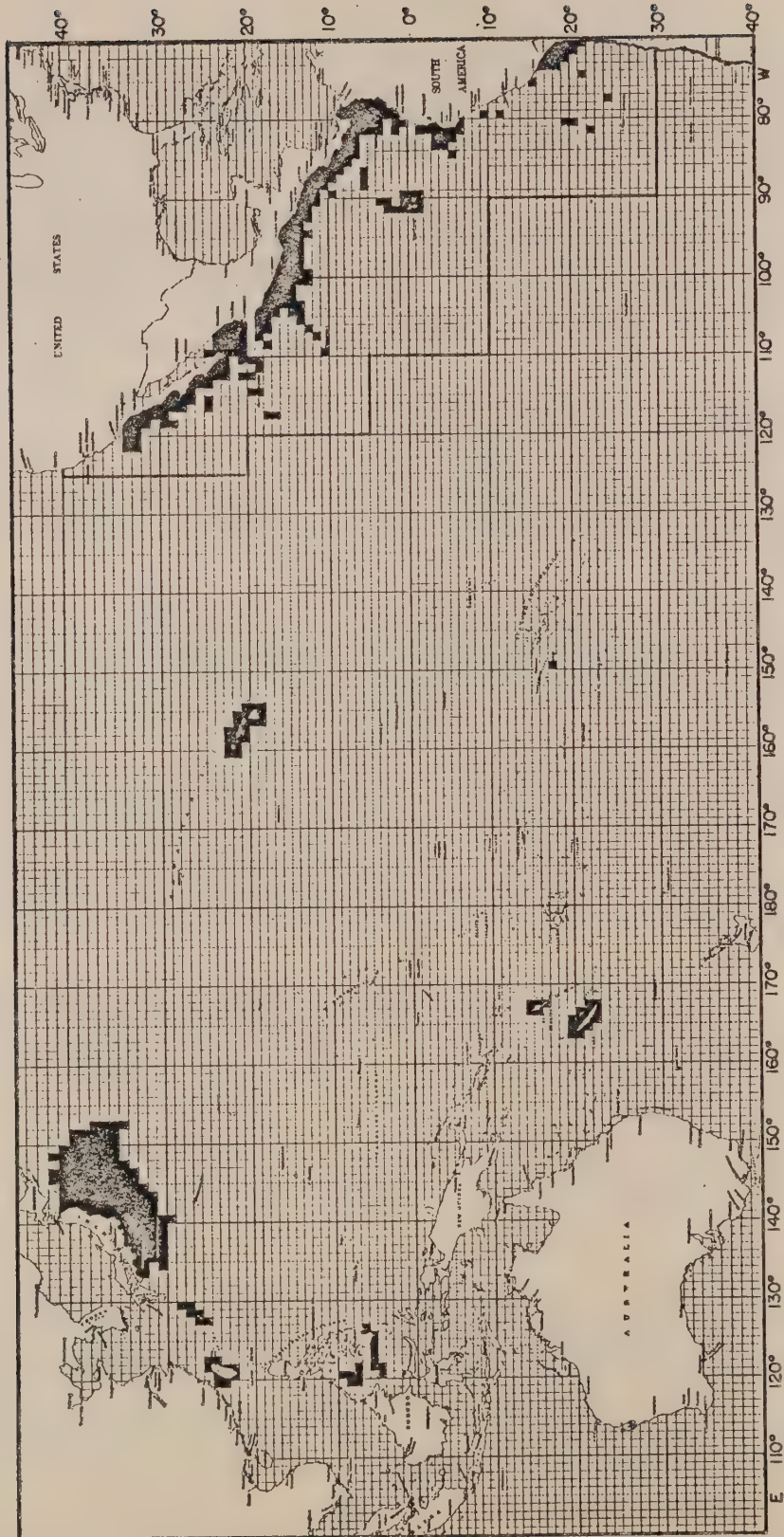
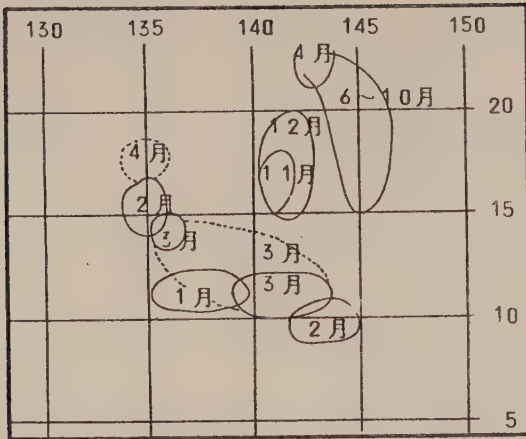
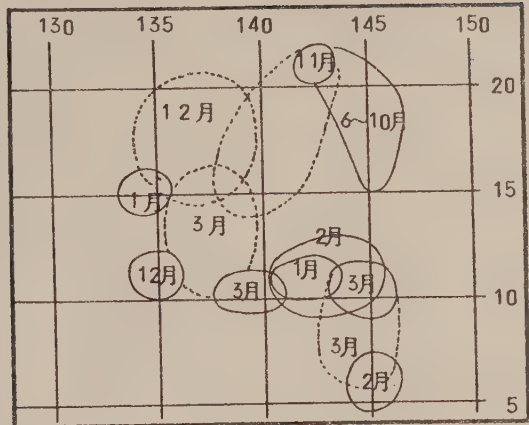


Figure 53.--Location of skipjack tuna fisheries in the Pacific Ocean in 1960.

1964 SEASON

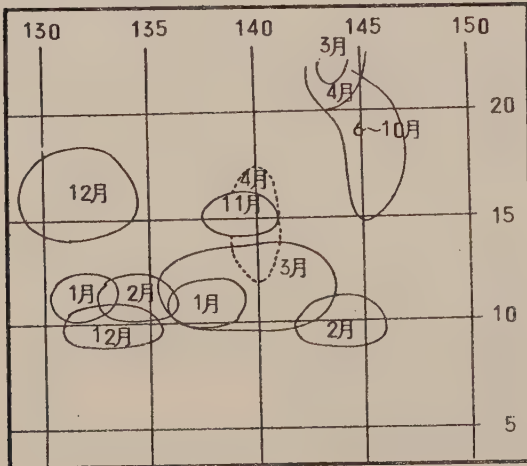


1966 SEASON



NUMBERS = MONTHS (月)

1965 SEASON



1967 SEASON

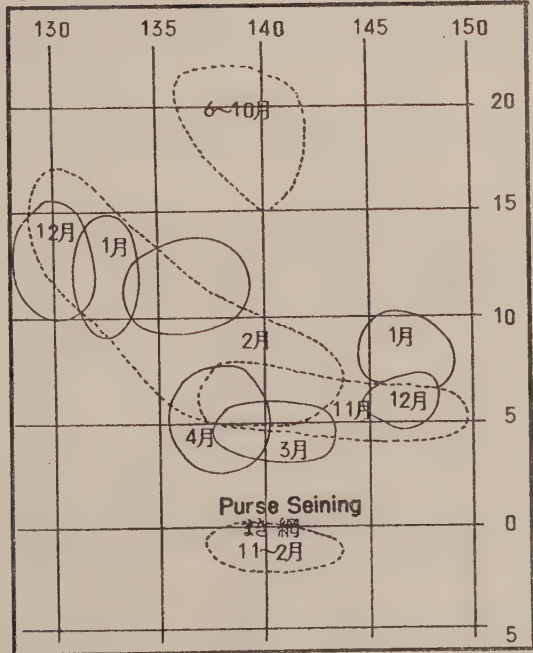
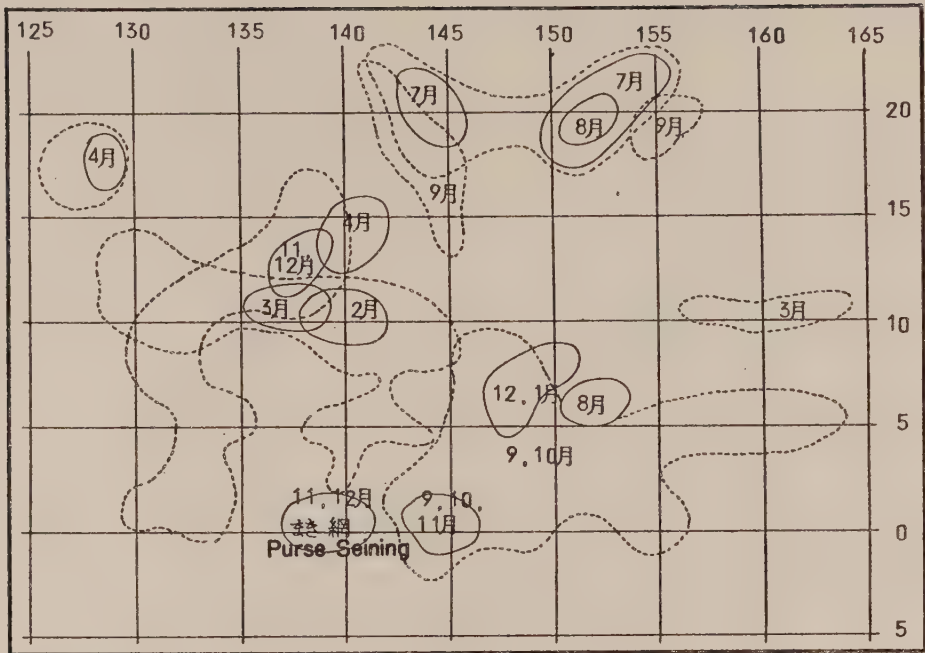


Figure 54.--The monthly movements of the skipjack tuna fishing grounds in southern waters. Areas of intense fishing effort encircled by solid line; area of moderate effort shown by broken line (Tohoku Regional Fisheries Research Laboratory, undated d). Note: Numerals denote months of year.

1968 SEASON



1969 SEASON

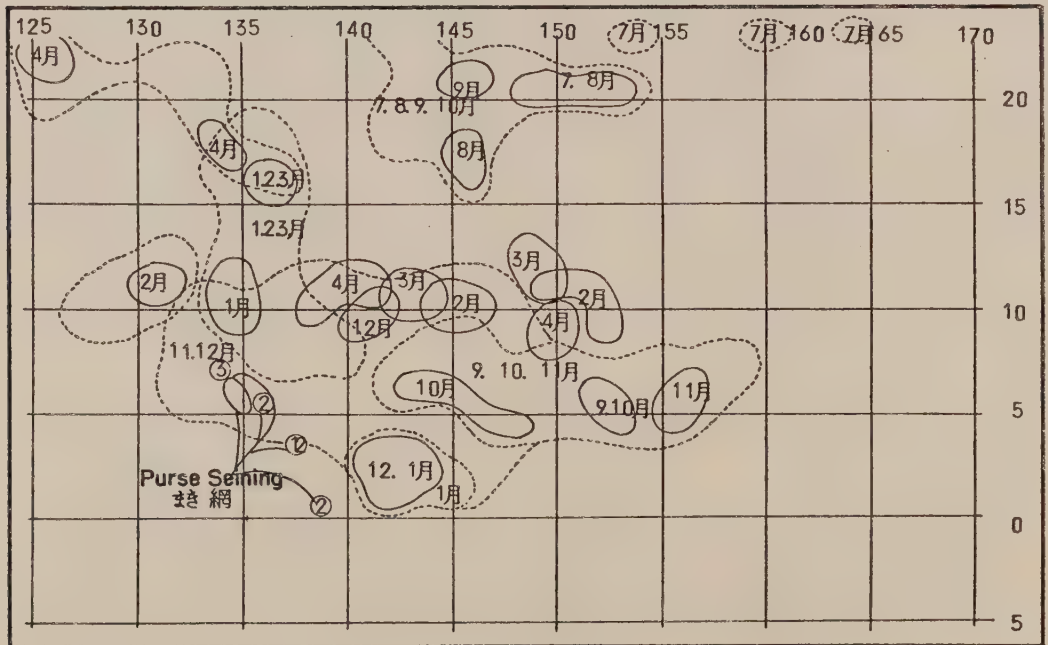


Figure 54.--Continued.

1970 SEASON

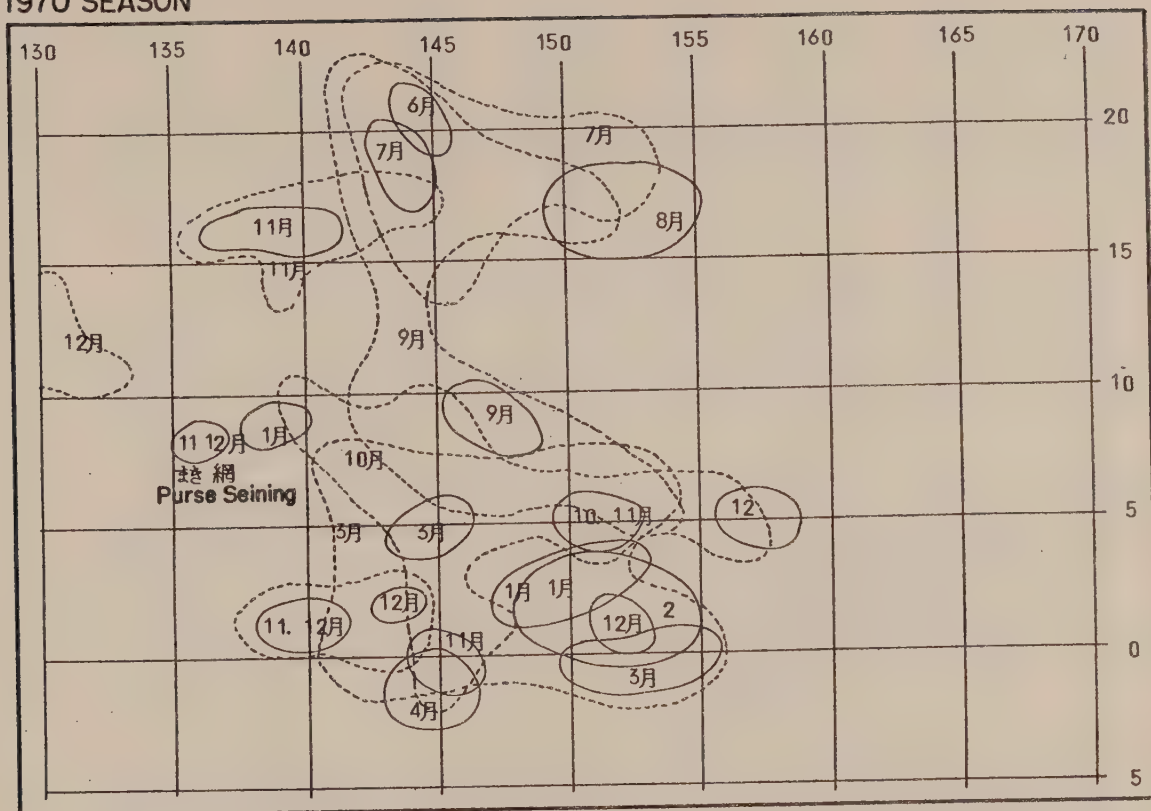


Figure 54.--Continued.

1971 SEASON

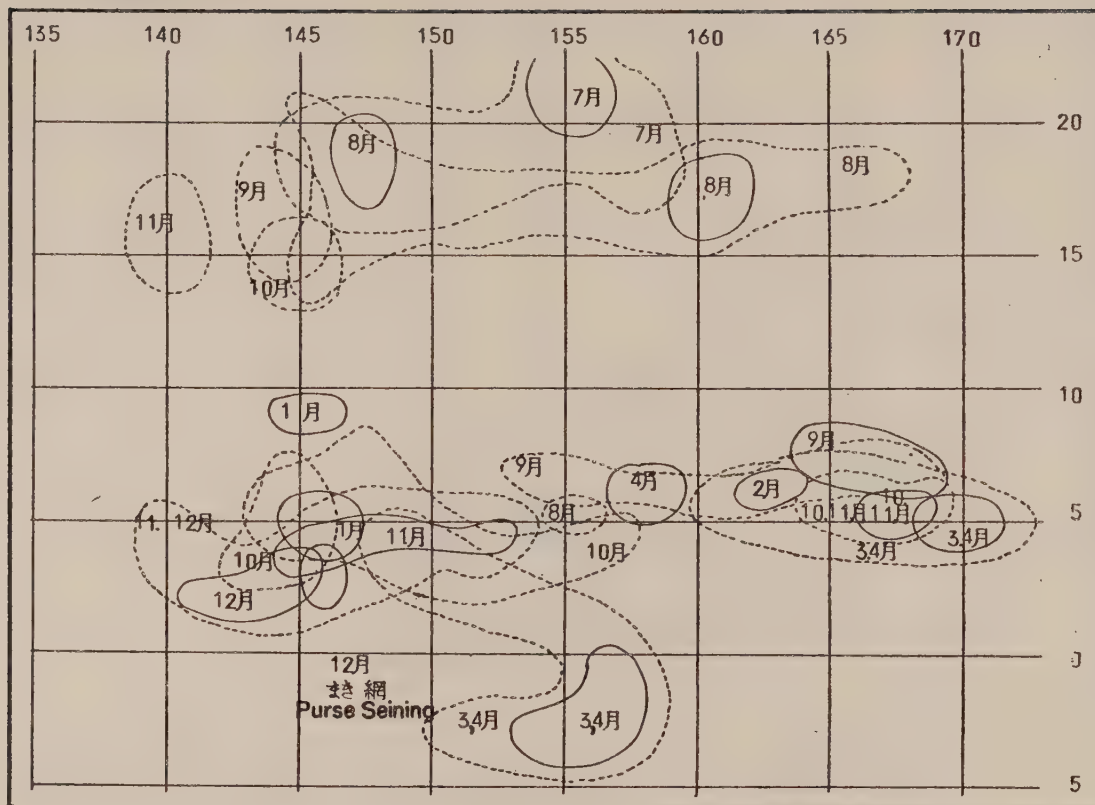


Figure 54.--Continued.

and 157°E. Generally, large vessels (>300 MT) tended to seek out and develop new, more distant fishing grounds, where the medium-sized vessels (about 200 MT) remained on the established grounds in spite of poor fishing. Figure 55 shows the extent of the fishing grounds for skipjack tuna not only in the southern water area but also throughout the Pacific basin in 1973.

Figure 56 shows the statistical areas established for the principal fishing ground in the southern water fishery whereas Table 27 shows percentage of fishing effort and catch per day's fishing in these statistical areas in 1963-69. In general, areas west of the Marianas and around the Western Carolines received a large proportion of the fishing effort.

The supply of live bait is an extremely important factor in the survival of the southern water fishery (U.S. National Marine Fisheries Service (NMFS), 1974d). Presently, all the bait used in this fishery is obtained in southern Japan and carried by the vessels to the fishing grounds. Bait-carrying capacity varies with vessel size; for example, a 190-ton vessel carries about 370 buckets of bait whereas a 350-ton vessel carried 500-600 buckets.

A trip to the southern water fishing grounds requires about 30 days but only a third of that time is spent fishing (U.S. NMFS, 1974d). The result of such long trips is high bait mortality which until recently varied from 30% to 60%. The major cause of bait mortality is the rapid rise in sea-surface temperature as the vessels steam southward from cold to warm water (U.S. NMFS, 1974d). Some Japanese researchers believe that higher water temperature is conducive to disease outbreak whereas others feel that increased temperature will promote spawning and, therefore, weaken the baitfish (Otsu, in press). To reduce bait mortality, Japanese improved bait-tank design and refrigerated the bait-tank water. Also, taking on "seasoned" anchovy which had been held in bait compounds and fed regularly for periods of a week to a month significantly reduced mortality. Survival rates in recent years have been 70%-80%.

Monitoring the southern water catches of skipjack tuna which were being landed at the port of Yaizu, Kasahara (1971) showed a pattern evolving among returning vessels. Generally, very few returning vessels fished the southern waters in May-June (Figure 57). In July, there was an increase followed by a slight decrease until October and another increase until December. There was a sudden decrease in January followed by another increase in February and March. The low numbers fishing in southern waters in May-June reflects the shift to albacore fishing in Japanese coastal waters. The increase in October reflects the end of the skipjack tuna season in coastal waters off Japan and many vessels then enter the southern water fishery. The January low reflects the tie-up of many vessels during the New Year's holidays.

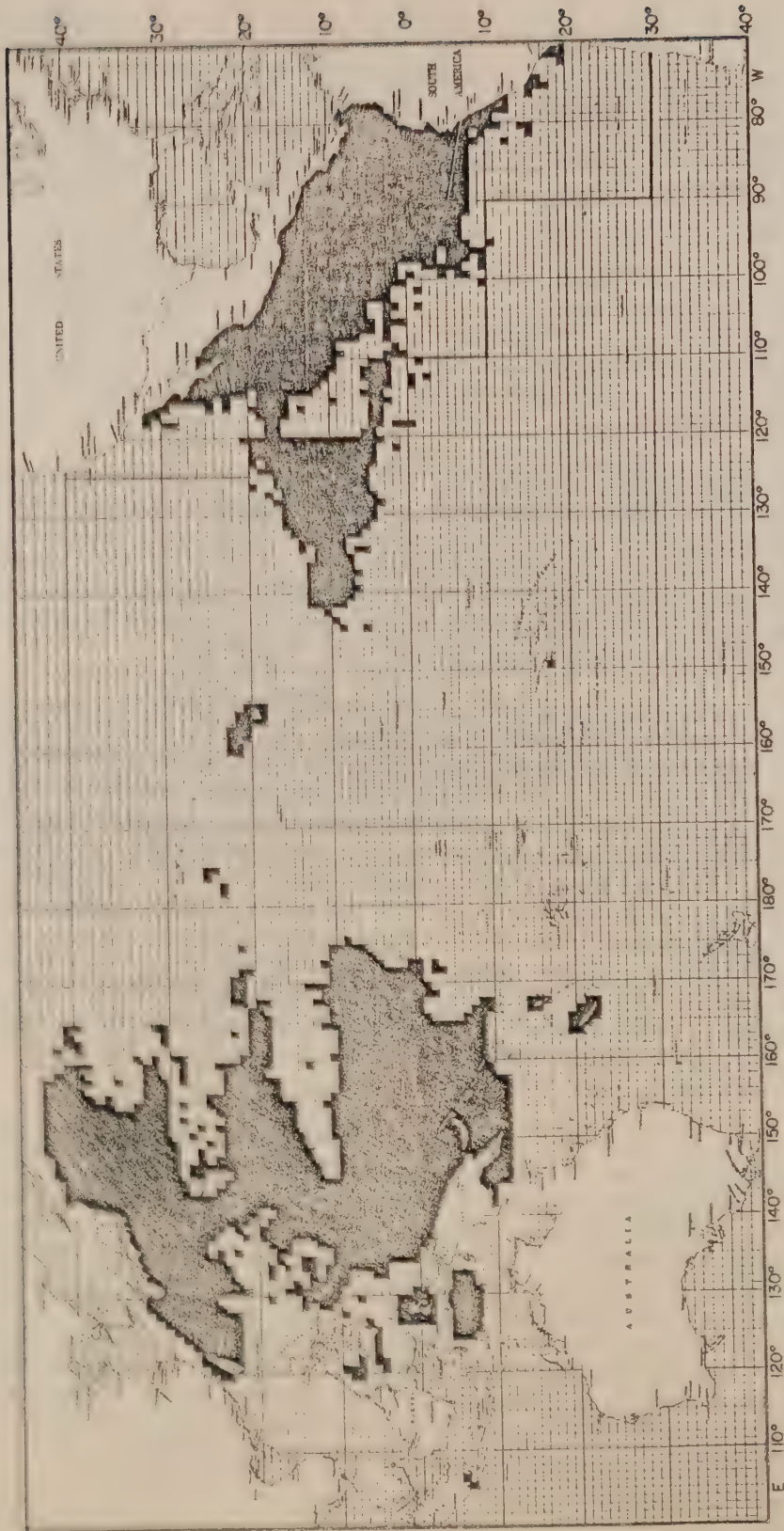


Figure 55.--Location of skipjack tuna fisheries and fishing areas in the Pacific Ocean in 1973.

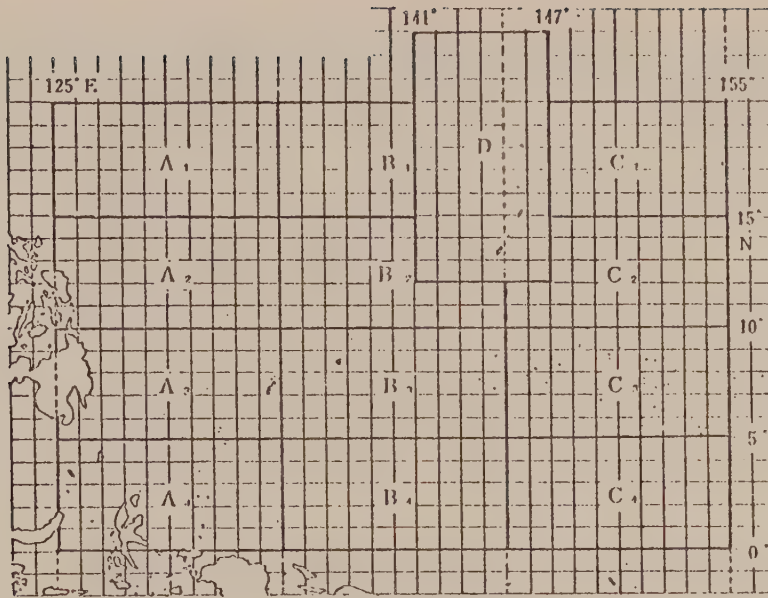


Figure 56.--The subdivision of the principal fishing area in southern waters from November through April (Kasahara, 1971).

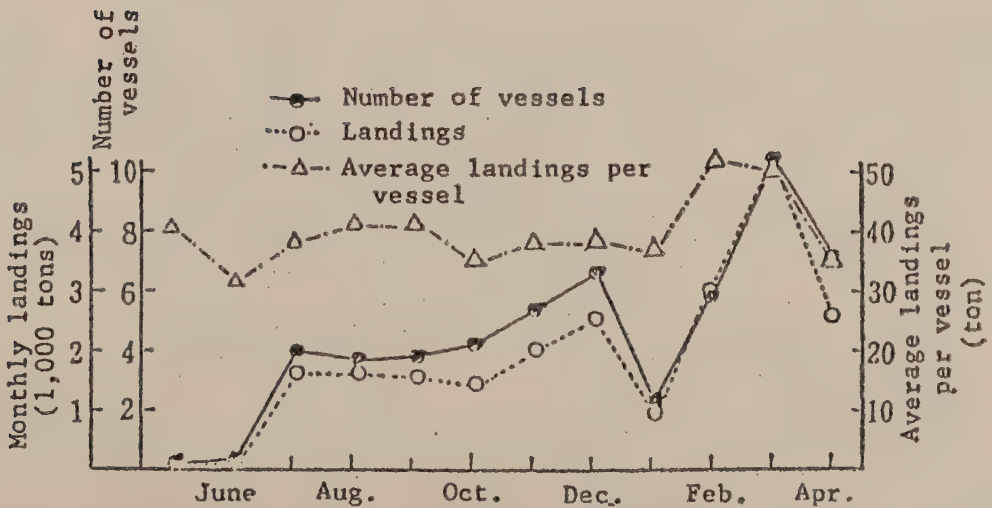


Figure 57.--The monthly average number of vessels, landings, and landings per vessel of vessels returning to Yaizu Port from the southern water fishery (averaged for the years 1964-70) (Kasahara, 1971).

Table 27.--The percentage fishing effort (upper row) and the catch per day's fishing (lower row), in tons, shown by sub-areas as designated in Figure 56 from November through April (Kasahara, 1971).

Sub-area	Season						
	1963	1964	1965	1966	1967	1968	1969
A ₁		3.3 3.2	5.9 3.6	5.7 4.4	0.5 5.4	5.6 4.1	11.1 6.2
A ₂		1.5 3.1	21.6 4.9	6.8 3.6	0.5 5.9	20.3 4.0	8.0 6.7
A ₃		0.6 3.5	3.6 6.1	1.8 3.9	0.8 5.9	3.4 6.6	4.6 5.5
A ₄						1.9 4.2	0.2 2.4
B ₁		11.1 4.1	5.8 3.0	14.5 4.0	0.7 3.9	2.3 2.4	7.1 5.4
B ₂		42.0 7.3	42.4 5.8	25.0 6.1	17.1 5.2	39.3 4.5	12.2 6.7
B ₃	37.0 7.6	3.7 7.1	6.4 8.8	12.3 5.3	32.0 6.0	7.8 4.1	23.7 5.2
B ₄				2.5 8.7	6.2 7.7	3.5 2.6	6.5 6.1
C ₁						1.1 6.5	
C ₂		0.6 9.1	0.3 5.7	0.3 9.2	1.4 4.4	0.3 2.8	5.5 9.0
C ₃		0.3 5.6	0.8 5.7	8.4 8.5	30.7 7.2	1.1 4.6	8.6 4.3
C ₄					4.6 10.8	1.1 4.9	3.0 4.2
D	50.0 3.4	36.6 4.6	12.4 3.8	21.4 3.7	4.7 4.2	1.6 2.3	0.5 3.4

The number of vessels returning from southern waters to Yaizu also reflects the landings at this port (Tohoku Regional Fisheries Research Laboratory, undated b). Usually, landings were high in November-December and February-March. Landings per trip show small variation ranging between 33 and 55 ST (30 and 50 MT). At the end of the 1971 fishing season, it was estimated that the southern water fishery for skipjack tuna contributed from 20% to 30% of the total Japanese skipjack tuna landings.

Table 28 gives the number of vessels returning monthly to Yaizu, monthly landings, landings per trip, and the seasonal landings in 1964-71. For the southern water fishery, a season extends from May to the following April. It should also be mentioned that landings of skipjack tuna caught in southern waters area are, at best, minimal because at Yaizu, they represent roughly 50%-80% of the total southern water fishery landings (U.S. NMFS, 1974d).

Based on Yaizu figures, it is apparent that the landings, except for 2 years, have grown from 15,454 ST (14,020 MT) in 1964 to 56,532 ST (51,286 MT) in 1971. The drop in landings in 1966 was attributed to a decrease in fishing intensity as many of the pole-and-line vessels experienced good fishing in coastal waters and remained there instead of heading for southern waters. In 1968, a typhoon in the Marianas curtailed fishing. Furthermore, it is believed that many vessels fishing further west in southern waters chose to unload at the ports of Makurazaki and Yamakawa.

Iwasaki (1970), who analyzed the variation in catch among vessels fishing in southern waters, noted that the trend toward higher seasonal landings does not necessarily reflect better average catches. Calculating the average annual catch of all vessels over 150 tons, Iwasaki found considerable annual variation (Figure 58). By area, Iwasaki found that in the Bonin-Mariana area the average catch per vessel was good in 1963-67 and poor in 1959-61 and 1968. In the Carolines area, average catches were rather stable; the exceptions were a very good season in 1967 and a very poor season in 1968.

Recognizing that when the average catch per vessel in the Bonin-Mariana area was high in July-September the catches were also above average in the Carolines in November-March, Iwasaki (1970) indicated that it may be possible to estimate the Carolines catches on the basis of the Bonin-Mariana catches. For the Bonin-Mariana area, Iwasaki found that variations in surface temperature and catch per vessel showed similar tendencies (Figure 59). Low temperature in 1963 and 1968 correlated positively with very poor fishing seasons. Temperatures were relatively high in 1964, 1967, and 1969, when fishing was good. He concluded that fishing condition for skipjack and yellow-fin tunas in the Bonin-Mariana area in any given year is largely influenced by prevailing water temperature.

Table 28.--Monthly number, total landings (estimated), and landings per vessel of vessels operating in southern waters and returning to Yaizu Port (Tohoku Regional Fisheries Research Laboratory, undated d).

MONTH	1964			1965			1966			1967		
	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL
MAY										8	277	34.5
JUNE	9	328	37.4	3	58	19.5				5	161	32.2
JULY	26	1,050	40.4	63	2,225	35.3	6	264	44.0	46	1,853	40.3
AUG.	37	1,771	47.8	49	1,724	35.2	24	903	37.6	29	1,363	47.0
SEPT.	40	1,559	39.0	43	2,084	48.4	23	972	42.3	30	1,225	40.9
OCT.	38	1,044	27.5	44	1,312	29.8	31	1,022	32.9	54	1,844	34.2
NOV.	38	1,215	32.0	52	1,528	29.4	56	1,929	34.5	67	3,110	46.5
DEC.	52	1,852	35.6	60	1,445	24.1	59	2,033	34.4	64	3,162	49.5
JAN.	7	305	43.6	19	702	36.9	26	1,090	42.0	67	1,754	26.2
FEB.	13	667	51.3	63	2,547	40.4	76	3,684	48.5	78	5,628	72.2
MAR.	86	3,443	40.1	136	6,484	47.5	123	5,881	47.8	100	4,729	47.3
APR.	24	735	30.6	66	2,212	33.5	53	1,883	35.6	61	3,216	52.7
TOTAL	370	14,020	37.9	598	22,321	37.3	477	19,661	41.2	609	28,292	46.7

MONTH	1968			1969			1970			1971		
	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL	NO. OF VESSELS	LANDINGS (TONS)	LANDINGS PER VESSEL
MAY	4	232	58.0									
JUNE	9	303	33.7	4	73	18.3				8	208	26.0
JULY	67	2,609	39.1	32	1,542	48.2	45	2,657	59.0	60	4,193	70.0
AUG.	44	1,897	43.1	38	1,847	48.6	35	1,833	52.4	89	6,049	68.0
SEPT.	35	1,178	33.7	40	1,864	46.6	35	1,652	47.4	45	2,673	59.5
OCT.	37	1,364	36.9	43	1,975	45.9	35	1,959	56.0	82	4,594	56.0
NOV.	46	1,561	34.0	48	2,516	52.4	71	3,613	50.9	94	6,857	73.0
DEC.	80	2,586	32.4	67	3,693	55.1	62	3,654	58.9	94	6,456	68.7
JAN.	11	719	65.4	9	588	65.3	12	927	77.2	15	1,243	82.9
FEB.	61	2,598	42.6	51	2,777	54.5	65	6,423	98.8	54	3,975	73.7
MAR.	74	3,058	41.3	108	7,421	68.8	78	6,065	77.7	77	6,183	80.3
APR.	71	3,123	44.0	86	3,934	45.7	63	4,454	71.0	66	6,152	93.2
TOTAL	539	21,228	39.5	526	28,230	53.9	501	33,237	66.5	2,713	51,286	71.9

1/ INCLUDES 55 TON CATCH OF 1 PURSE SEINER.

2/ INCLUDES 2,703 TONS TAKEN BY 29 VESSELS IN MAY 1972.

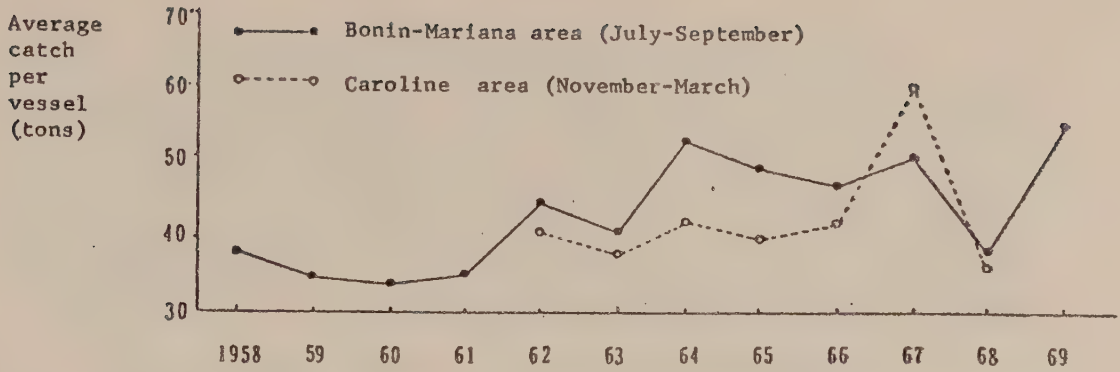


Figure 58.--The variations in annual average catch (Iwasaki, 1970).

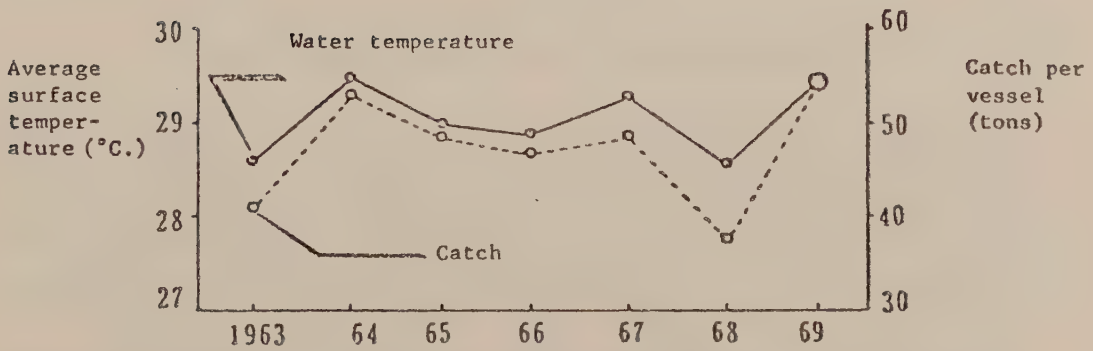


Figure 59.--Annual variations in water temperature and catches (Iwasaki, 1970).

In areas where fishing is good, the Japanese pole-and-line vessels average up to 8.8 ST (8 MT) of fish per vessel per day of fishing (Figure 60) (U.S. NMFS, 1971c). In October 1971, for example, the vessels reported that on the main fishing ground located near the equator and lat. 8°N between long. 150° and 160°E (between Truk and Greenwich Islands south of Ponape), the catch was 3.3-6.6 ST (3-6 MT) of skipjack tuna per vessel per day. Further north near lat. 14°-20°N and between long. 142° and 148°E (between Guam and Uracas Island in the Marianas), the catch per vessel per day was slightly better, averaging between 4.4 and 8.8 ST (4 and 8 MT).

Although small, the landings of yellowfin tuna caught by the pole-and-line vessels operating in southern waters should be mentioned. Kikawa and Warashina (1972) have studied the landings of yellowfin tuna and found that they averaged 4.9% of the total landings with monthly averages varying between 1.6% and 9.9%. The sizes of these yellowfin tuna ranged from 1 to 43 lb (0.5 to 19.5 kg) but most were between 3 and 5 lb (1.4 and 2.3 kg). Kikawa and Warashina also estimated that the number of fishing days with catches of yellowfin tuna averaged 30.1% with monthly averages between 16.8% and 48.3%.

Japanese Southern Water Purse Seine Fishery

In 1972, Yabe reported that anchovy, which are used as live bait by Japanese pole-and-line vessels, survive for a maximum of 50 days, but more normally for only about 5 weeks. Therefore, even if larger pole-and-line vessels are built, their operating range will still be limited and their eastern limit will probably be around the Marshalls. Yabe estimated that about 40 Japanese tuna longline vessels will be replaced each year by pole-and-line vessels and that within 3 years there may be as many as 200 large pole-and-line vessels fishing in southern waters. He anticipated serious problems from the standpoint of scarcity of bait for all the large vessels. Since purse seiners are not dependent on live bait, Yabe encouraged more rapid development of the tuna purse seine fishery in Japan.

Japanese attempts to capture surface schools of tuna with purse seine in southern waters started in 1964 when Taiyo Fishing Company dispatched the 240-ton seiner, Kenyo Maru, to the New Guinea-New Zealand area (Watakabe, 1970). Attempts to seine large- and medium-sized schools of skipjack tuna in waters north of New Guinea failed. In 1966, the Japanese Fisheries Agency undertook the development of tuna purse seining, and a full-scale test was started in the western equatorial Pacific during the slack, winter months (early November through mid-March) in the coastal waters of Japan.

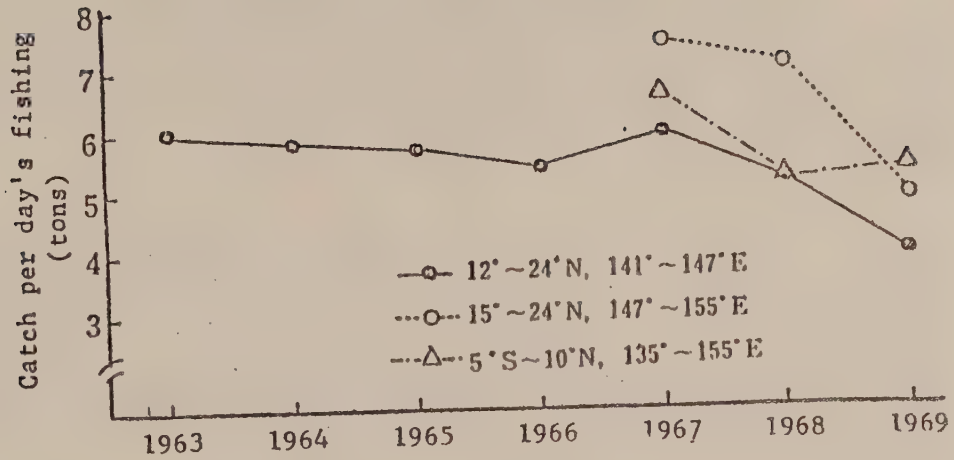


Figure 60.--The catch per day's fishing of skipjack tuna vessels in southern waters from May through October (Kasahara, 1971).

Watakabe (1970) reported on these early trials, which were held near the equator (lat. 0° - 5° N, long. 137° - 140° E) to the north of New Guinea and near Palau Islands. The Japanese purse seiners experienced a success rate of only 30% in these early trials. Problems with variable weather, clear water, deep thermocline, and subsurface currents have all hindered the progress of exploratory purse seining in the western Pacific.

The erratic behavior of skipjack tuna schools in the western Pacific has also been mentioned as a cause of failure in purse seining (Watakabe, 1970). Many of the schools in the vicinity of islands and banks are feeding on young sardine or flying fish and can be seen breaking the surface and causing the water to "boil." These fish aggregate in large schools. Offshore schools appear to be moving faster and often the direction of movement is unpredictable. The catch records of four seiners that operated in Trust Territory waters in 1966-69 are given in Table 29.

In the early 1970's the semi-government Japan Marine Fishery Resources Research Center (JAMARC) assumed responsibility for the developmental work in purse seining (U.S. NMFS, 1974d). In October 1970-March 1971, two seiners were chartered to continue exploratory fishing. And although these seiners captured up to 19.8 ST (18 MT) of skipjack tuna in a single set, most of the catches were smaller (Table 30). The conclusions drawn from these tests were that skipjack tuna schools can be seined in tropical waters under certain conditions, that seinable schools are found associated with floating logs, and that purse seine success rate is increased if sets are made at dawn or dusk rather than during midday (Yabe, 1972).

In 1974, JAMARC chartered the 499-GT purse seiner, Fukuichi Maru, which made three exploratory purse seining cruises around the Marshalls and Carolines (U.S. NMFS, 1974a, 1974b). During the first 2-month survey, the seiner caught 252 ST (229 MT) of skipjack tuna and 58 ST (53 MT) of yellowfin tuna, a total of 310 ST (282 MT) of tuna in 27 sets or an average of 11.5 ST (10.4 MT) per set (U.S. NMFS, 1974c; Otsu, in press). On her second cruise to the southeast of Palau, Fukuichi Maru found fishing slower. In 10 sets, 24 ST (22 MT) of skipjack tuna and 36 ST (33 MT) of yellowfin tuna were taken or an average of 6.1 ST (5.5 MT) of tuna per set. The third cruise started in the Eastern Carolines (lat. 4° - 8° N and long. 145° - 151° E) where three sets yielded 20 ST (19 MT) of fish. Heading to waters southeast of Palau, the seiner continued to experience poor fishing. Fourteen sets yielded 140 ST (127 MT) or an average of 10.0 ST (9.1 MT) per set. Toward the end of the survey, Fukuichi Maru caught 22 ST (20 MT) in one set at lat. 2° N and long. 144° E.

Table 29.--Catch records of four Japanese purse seiners operating in southern waters, 1966-69 (Watakabe, 1970).

Vessel	Year			
	1966	1967	1968	1969 (1 trip only) ¹
<u>No. 3 Hayabusa Maru</u>		(3 trips) Skipjack 80 tons Yellowfin 50 tons	(1 trip) Skipjack 60 tons	Skipjack 67 tons
<u>No. 23 Taikei Maru</u>	(3 trips) Skipjack 104 tons Yellowfin 31 tons	(2 trips) Skipjack 43 tons Yellowfin 5 tons	(3 trips) Skipjack 80 tons Yellowfin 36 tons	Did not fish
<u>Nissho Maru</u>	(1 trip) No catch	(4 trips) Skipjack 146 tons Yellowfin 56 tons	(1 trip) Skipjack 26 tons Yellowfin 56 tons	Skipjack 53 tons Yellowfin 25 tons
<u>No. 58 Tokiwa Maru</u>		(3 trips) Skipjack 73 tons Yellowfin 102 tons	Did not fish	Skipjack 81 tons

¹Translator's note: These figures for 1969 do not exactly correspond with data presented on preceding page.

Table 30.--Results of experimental purse seining by Japanese Government chartered vessels, Taikei Maru No. 23 (210 gross tons) and Tokiwa Maru No. 58 (358 gross tons) (Japan Fisheries Agency, undated).

DATE	POSITION	TIME OF DAY	TYPE OF SCHOOL SET ON	CATCHES MADE	VESSEL
11/9/70	00°09'S, 143°36'E.	0455	Drift log; small YF; found by fish finder.	No catch.	No. 23 TAIKEI
11/11/70	05°53'N, 144°57'E	0814	do	do	Do
11/12/70	07°02'N, 146°49'E	1625	With whale shark; small YF jumping.	10 YF (30-40 kg.) 2 tons of small YF (4-6 kg.)	Do
11/14/70	06°37'N, 149°39'E	1243	Skipjack jumping.	3 tons of small YF (3-4 kg.)	Do
11/15/70	06°37'N, 150°20'E	1200	Skipjack with bird flock.	5 tons of small YF (3-4 kg.)	Do
11/16/70	06°50'N, 151°12'E	1200	Drift log and small YF.	No catch.	Do
11/22/70	03°06'S, 149°26'E	0755	Skipjack jumping; bird flock.	No catch.	Do
11/23/70	03°00'S, 149°23'E	1141	Drift log; skipjack jumping; many schools in vicinity.	No catch; Auxis escaped net.	Do
11/30/70	03°58'S, 147°01'E	1438	Skipjack jumping.	0.5 ton of skipjack (3 kg.)	Do
12/2/70	02°54'S, 145°07'E	1400	Skipjack jumping; bird flock.	7 tons of skipjack (2-3 kg.)	Do
12/15/70	08°34'N, 141°45'E	1550	With whale shark; small YF jumping.	No catch	Do
11/30/70	09°29'N, 133°32'E	0840	Drift log and YF.	11 YF (20-25 kg.)	No. 58 TOKIWA
12/10/70	02°16'N, 140°14'E	1040	Drift log and YF.	1 YF	Do
12/12/70	05°06'N, 139°33'E	1020	With drifting bamboo; school on fish finder.	1.5 tons of skipjack (3-4 kg.)	Do
12/16/70	09°36'N, 133°59'E	1216	Skipjack with whale shark.	17 tons of skipjack (4-5 kg.)	Do
1/21/71	02°46'N, 138°47'E	1140	Skipjack breezing school.	No catch.	No. 23 TAIKEI
2/3/71	03°43'S, 149°07'E	0615	Small skipjack school.	2 tons of skipjack (2-3 kg.)	Do
2/5/71	03°48'S, 146°19'E	1055	do	1.5 tons of skipjack (3 kg.)	Do
2/9/71	01°41'S, 143°35'E	0800	Skipjack breezing school.	No catch.	Do
2/9/71	01°36'S, 143°35'E	1200	do	No catch.	Do
2/10/71	02°00'S, 142°25'E	1610	Small school skipjack with bird flock.	1 ton skipjack (2-3 kg.)	Do
2/11/71	02°07'S, 142°21'E	0805	"Boiling" skipjack school with bird flock.	No catch.	Do
2/12/71	02°00'S, 141°35'E	1330	Small breezing school of skipjack.	No catch.	Do
2/13/71	02°31'S, 142°28'E	1505	Small breezing SJ school with birds.	5 tons of SJ (2-3 kg.)	Do
3/5/71	03°12'N, 139°15'E	0525	Drift log, small school.	1 ton of YF (10-15 kg.)	Do
3/7/71	03°38'N, 135°20'E	1345	Drift log, small school.	0.3 ton of YF (1-1.5 kg.); 0.7 ton rainbow runner.	Do

Table 30.--Continued.

DATE	POSITION	TIME OF DAY	TYPE OF SCHOOL SET ON	CATCHES MADE	VESSEL
3/11/71	06°00'N, 140°00'E	1300	Jumping yellowfin with birds.	No catch	No. 23 TAIKEI
3/11/71	05°54'N, 140°08'E	1745	do	9 YF (40 kg.)	Do
3/12/71	05°38'N, 140°31'E	1715	do	No catch.	Do
3/13/71	05°49'N, 140°36'E	0645	School with drift log.	6 tons YF; 2 tons small YF; 2 tons SJ	Do
3/15/71	05°49'N, 140°10'E	0615	do	1 ton YF; 4 tons small YF; 10 tons SJ	Do
1/25/71	06°46'N, 139°43'E	0947	"Boiling" school of SJ with birds.	8 tons SJ (3 kg.)	No. 58 TOKIWA
2/8/71	00°05'S, 146°47'E	0520	Small school YF with drift log.	1 ton YF (25-30 kg.)	Do
2/23/71	00°11'S, 141°05'E	0545	SJ-YF mixed school with drifting bamboo.	1.5 ton YF (2-3 kg.); 1.5 ton SJ (3-4 kg.)	Do
3/13/71	05°56'N, 140°24'E	0532	do	18 tons SJ (3-4 kg.); 2 tons YF (10-20 kg.)	Do
3/13/71	05°50'N, 140°28'E	1328	Jumping YF school.	No catch.	Do
3/15/71	06°10'N, 140°05'E	0512	SJ-YF mixed school with drift log.	2 tons SJ (3-4 kg.); 6 tons YF (3-20 kg.)	Do

1/ The Government (Japan Fisheries Agency) chartered the two purse seiners to conduct experimental purse seining in tropical waters. The specifications on the vessels and on the nets used by the two vessels are as follows:

No. 23 Taikei Maru (210 tons)		No. 58 Tokiwa Maru (358 tons)	
Length	34.0 m	43.7 m	Do
Width	7.8 m	9.0 m	Do
Speed	10 knots	10.5 knots	Do
No. in crew	16	21	Do
Purse seine depth	240 m	300 m	Do
Bunt	150 m long	150 m long	Do
Main body	1,395 m long	1,305 m long	Do

(At completion of charter, the vessels apparently began commercial seining in same general areas and results appear to be rather encouraging (--personal communication).)

For three cruises, then, Fukuichi Maru set on 53 schools associated with drifting objects and caught 185 ST (168 MT) of yellowfin tuna, 353 ST (320 MT) of skipjack tuna, and 13 ST (12 MT) of miscellaneous species.

Because of the success of Japanese seiners in setting around skipjack tuna and yellowfin tuna schools that are associated with drifting objects, Japanese researchers have initiated studies on the possibility of aggregating tuna under artificial drifting objects (Otsu, in press). Preliminary results have already indicated that there is some merit in this approach.

At present, Japanese fishermen consider purse seining to be commercially feasible and several commercial seiners are operating in the western Pacific and in the Coral Sea (Otsu, in press). Overall, the catches are averaging 11 ST (10 MT) per set and about 80% of the sets are successful in catching tuna. Compared to United States seiners in the eastern tropical tuna fishery, Japanese seiners are considerably smaller, varying from 250 to 500 GT, and average smaller catches per set. The Japanese fishermen believe that they can achieve success under the following conditions:

1. Schools must be associated with drifting objects (driftwood, etc.).
2. Sets must be made either early in the morning or at dusk.
3. Nets must be larger than those used in the eastern Pacific.

When a school is found associated with a drifting object, a seiner may often follow it until dusk or early morning (Otsu, in press). Marking the drifting object with a radio buoy or lights, the seiner may track a school overnight and set on it in the early morning.

Table 31 gives the dimensions of the nets used by Japanese tuna purse seiners.

Japanese Longline Fishery Development

Longline fishing for subsurface tunas in the western Pacific was reestablished by the Japanese after the end of World War II in the area authorized for Japanese fishing by the Supreme Commander for the Allied Powers (SCAP) on 22 June 1946 (Figure 61). On 11 May 1950, roughly 4-1/2 years after the war, a new phase of the Japanese tuna longline fisheries was launched when the Commander-in-Chief, U.S.

Table 31.--Dimension of nets used by Japanese purse seiners operating in the western equatorial Pacific Ocean (Otsu, in press).

<u>Vessel</u>	<u>Area used</u>	<u>Size of net</u>
<u>Nippon Maru</u>	Eastern Pacific and West Africa (U.S.-type seiner)	110 m deep x 1,025 m long or 118 m deep x 1,350 m long
<u>Hayabusa Maru</u>	North of Papua New Guinea	220 m deep x 1,600 m long
<u>No. 58 Tokiwa Maru</u>	North of Papua New Guinea	250 m deep x 1,960 m long
<u>No. 55 Hakuryu Maru</u>	Japan coastal waters for skipjack and yellowfin tunas	150 m deep x 1,500 m long or 220 m deep x 1,500 m long
<u>Wakaba Maru</u>	do.	220 m deep x 1,500 m long
<u>No. 23 Taikei Maru</u>	do.	200 m deep x 1,500 m long
<u>No. 28 Kohoku Maru</u>	do.	261 m deep x 2,025 m long
<u>No. 85 Seishin Maru</u> (two-boat seining)	do.	350 m deep x 1,700 m long
<u>No. 7 Konpira Maru</u> (two-boat seining)	do.	240 m deep x 2,400 m long

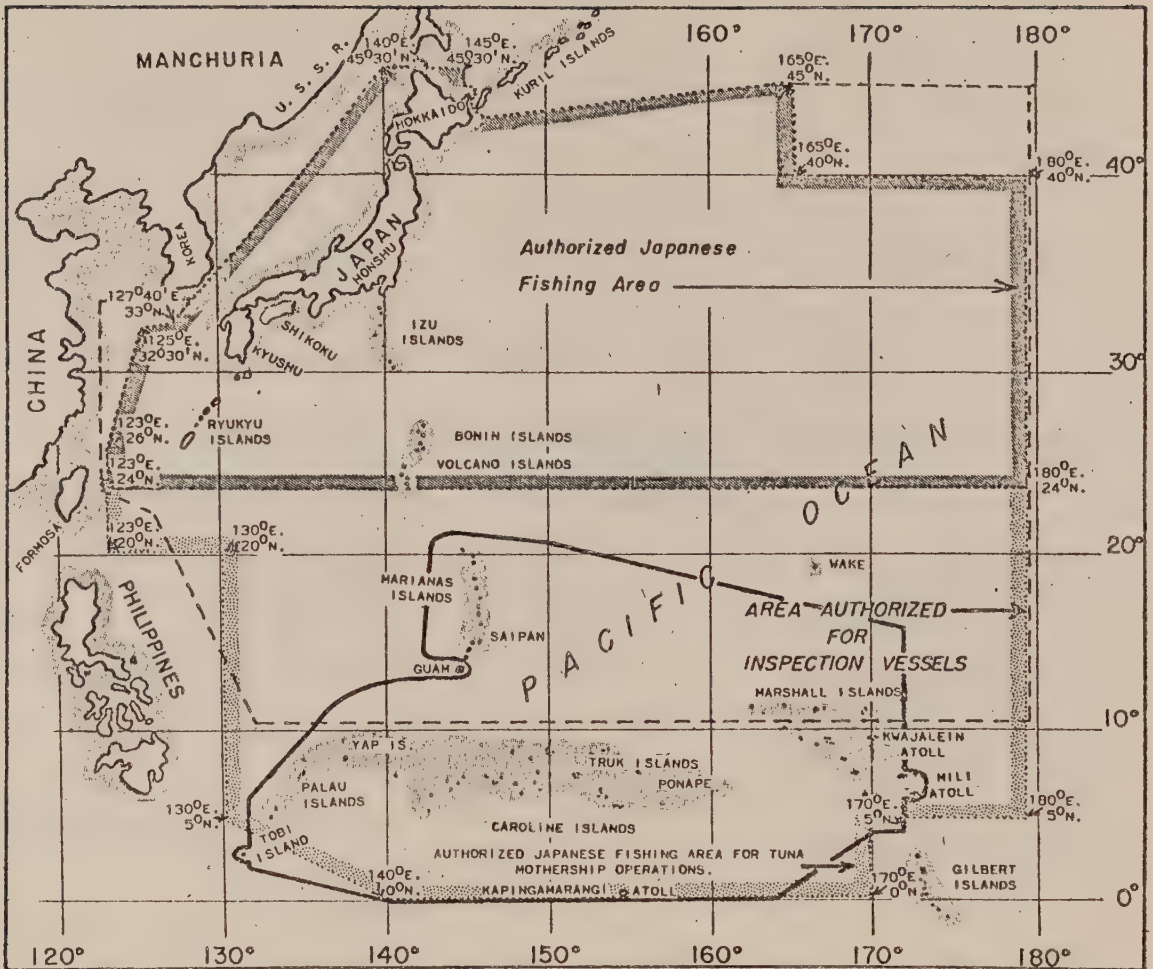


Figure 61.--Horizontally lined border indicates extent of the CINCPAC-SCAP authorized Japanese fishing area as of 11 May 1950. Broken black line indicates area authorized for Japanese inspection vessels. Dotted-stippled border shows extension south of lat. 24°N to the equator for Japanese tuna mother ship operations. Solid black line around Mariana, Marshall, and Caroline Islands shows the U.S. Trust Territory of the Pacific Islands (Shimada, 1951).

Pacific Fleet (CINCPAC) and SCAP permitted the Japanese to send tuna mother ship expeditions to defined areas of the high seas adjacent to the Carolines, Marianas, and Marshalls (Shimada, 1951).

Figure 61 shows not only the original area authorized by SCAP, but also the area authorized for inspection vessels and that designated for mother ship operations. The first mother ship fleet, consisting of a large refrigerated carrier and 25 longline vessels, was outfitted in Japan and began fishing on 17 June 1950 (Shimada, 1951). The general area of operation in Trust Territory waters is shown in Figure 62.

The total catch in 79 days of operation in waters south of the Carolines (between 17 June and 5 September) reached 8,118,834 lb (3,683 MT) (Shimada, 1951). Table 32, which shows the catch by species, indicates that among the subsurface tunas in Trust Territory waters, the yellowfin tuna was by far the most abundant, comprising 50% of all the fish landed. Next in importance was the bigeye tuna. Albacore, bluefin, and skipjack tunas comprised only a small percentage of the catch.

Shimada (1951) noted that the catcher boats attached to the expedition experienced catches that fluctuated widely. The average catch per vessel, shown in Figure 63, was high when operations first commenced but fell to about 2.2-2.8 ST (2.0-2.5 MT) per vessel per day as the peak fishing season in May-June passed. The expedition moved eastward and found new productive grounds. In mid-July, the vessels had several days of good fishing in waters adjacent to Kapingamarangi near lat. 1° - 2° N between long. 153° and 154° E. In late July and early August, some of the best fishing was encountered near Kapingamarangi. Based on current drifts, Shimada believed that the zone of good fishing was probably within the Equatorial Countercurrent and close to its southern border. In late August, catches fell to lower levels at the close of the season and as the expedition shifted northward out of the productive area.

Catch rates, according to Shimada (1951), were 3.23 tunas and spearfishes per 100 hooks and 3.85 fish for all species. In contrast, Nakamura (1943) reported an average of 6.05 fish per 100 hooks from Trust Territory waters in prewar years. According to the fishermen, changes in hydrographic conditions were probably most responsible for the lower catches made by the expedition.

After the initial tuna mother ship operation and until October 1951, eight others took place (Murphy and Otsu, 1954). General observations on the methods, catch, and area fished during these expeditions have been published in Ego and Otsu (1952) and Van Campen (1952). Table 33 shows the size, operating area, and period

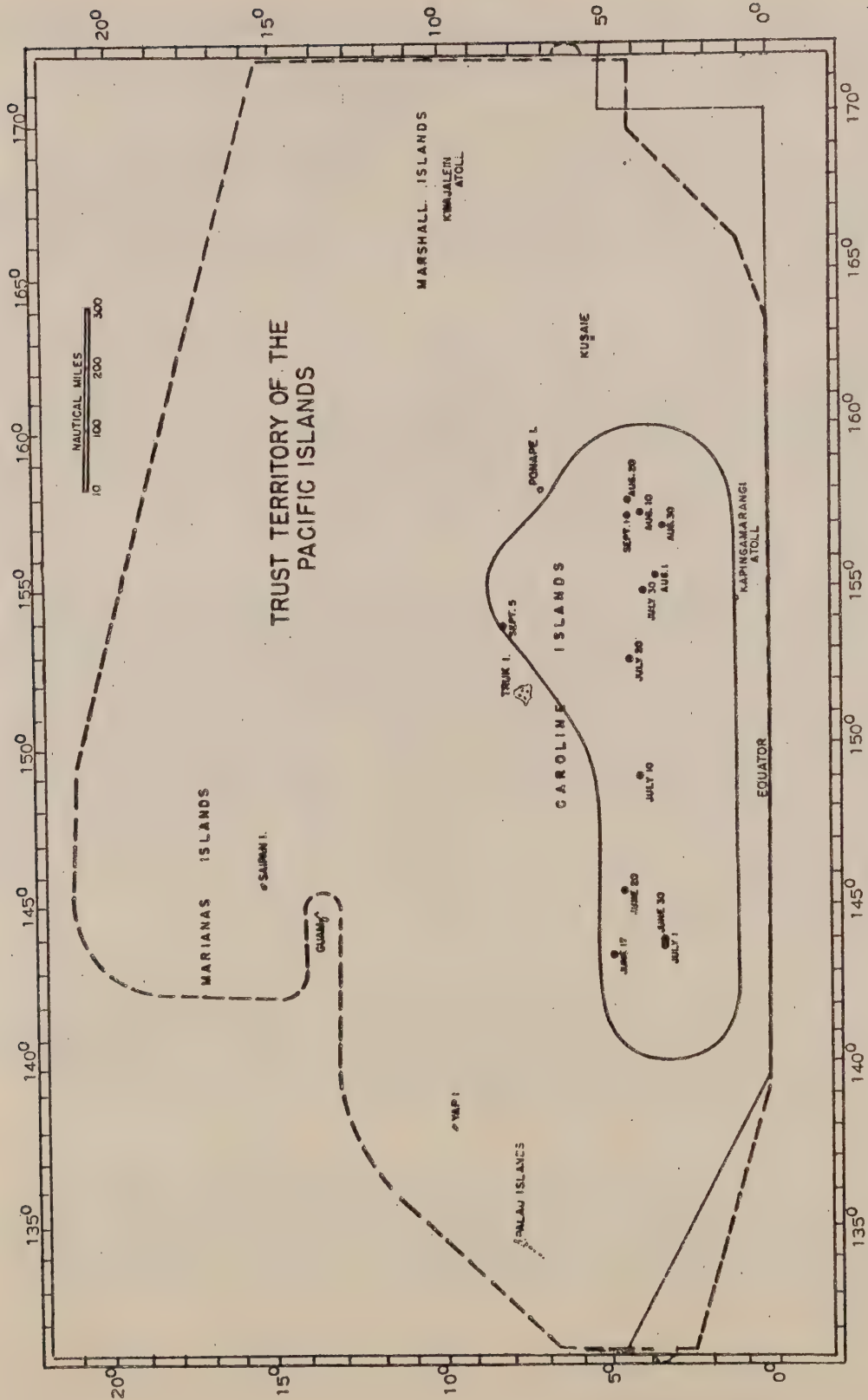


Figure 62.--General area of operations (solid black line) in waters surrounding Trust Territory of the Pacific Islands (dotted line) of the first Japanese tuna mother ship expedition. Dated positions are those of the mother ship during the season, from 17 June to 5 September 1950 (Shimada, 1951).

Table 32.--Total catch, by species, of the first Japanese tuna mother ship expedition, June-September 1950 (Shimada, 1951).

Species	Quantity Caught
	Lbs.
Yellowfin tuna (<i>Neothunnus macropterus</i>)	4,574,358
Big-eyed tuna (<i>Parathunnus sibi</i>)	699,014
Albacore (<i>Thunnus germon</i>)	65,378
Bluefin tuna (<i>Thunnus orientalis</i>)	3,430
Skipjack (<i>Katsuwonus pelamis</i>)	6,968
Black marlin (<i>Makaira mazara</i>)	1,760,389
White marlin (<i>Makaira marlina</i>)	48,182
Striped marlin (<i>Makaira mitsukurii</i>)	1,229
Sailfish ^{2/} (<i>Istiophorus orientalis</i>)	28,160
Swordfish (<i>Xiphias gladius</i>)	13,656
Shark	895,022
Others ^{3/}	23,048
Total	8,118,834

1/STATISTICS PROVIDED BY THE JAPANESE FISHERY AGENCY AND CONVERTED TO POUNDS, USING THE CONVERSION FACTOR OF 8.27 LBS. = 1 KAN.
2/INCLUDES SHORT-NOSED MARLIN (*TETRAPTURUS BREVIROSTRIS*).
3/INCLUDES BARRACUDA (*SPHYRAENA ARGENTEA*), WAHOO (*ACANTHOCYBIUM SOLANDRI*), AND DOLPHIN (*CORYPHAENA HIPPURUS*).

Table 33.--Size, operating area, and period of the Japanese tuna mother ship expeditions in the western equatorial Pacific Ocean (June 1950-June 1951) (Ego and Otsu, 1952).

Expedition	Motherships		No. Catcher Vessels	Area Fished	Period Fished
	Name	Gross Tonnage (Metric tons)			
I	Tenyo Maru No. 2	10,619	25	10°-9°N. lat.; 140°-157°E. long.	June 17, 1950 - September 5, 1950
II	Kaiko Maru	2,940	13	10°-7°N. lat.; 157°-169°E. long.	July 20, 1950 - September 30, 1950
III	Tenryu Maru	577	6	10°-5°N. lat.; 134°-141°E. long.	December 1, 1950 - December 26, 1950
IV	Tenryu Maru Tosui Maru	577 362	11	10°-6°N. lat.; 156°-161°30'E. long.	February 1, 1951 - February 24, 1951
V	Tenyo Maru No. 3 Banshu Maru No. 35	3,689 999	16	10°-6°N. lat.; 137°-165°E. long.	March 21, 1951 - June 13, 1951
VI	Tenryu Maru Tosui Maru	577 362	8	10°-6°N. lat.; 157°-163°E. long.	April 22, 1951 - May 25, 1951

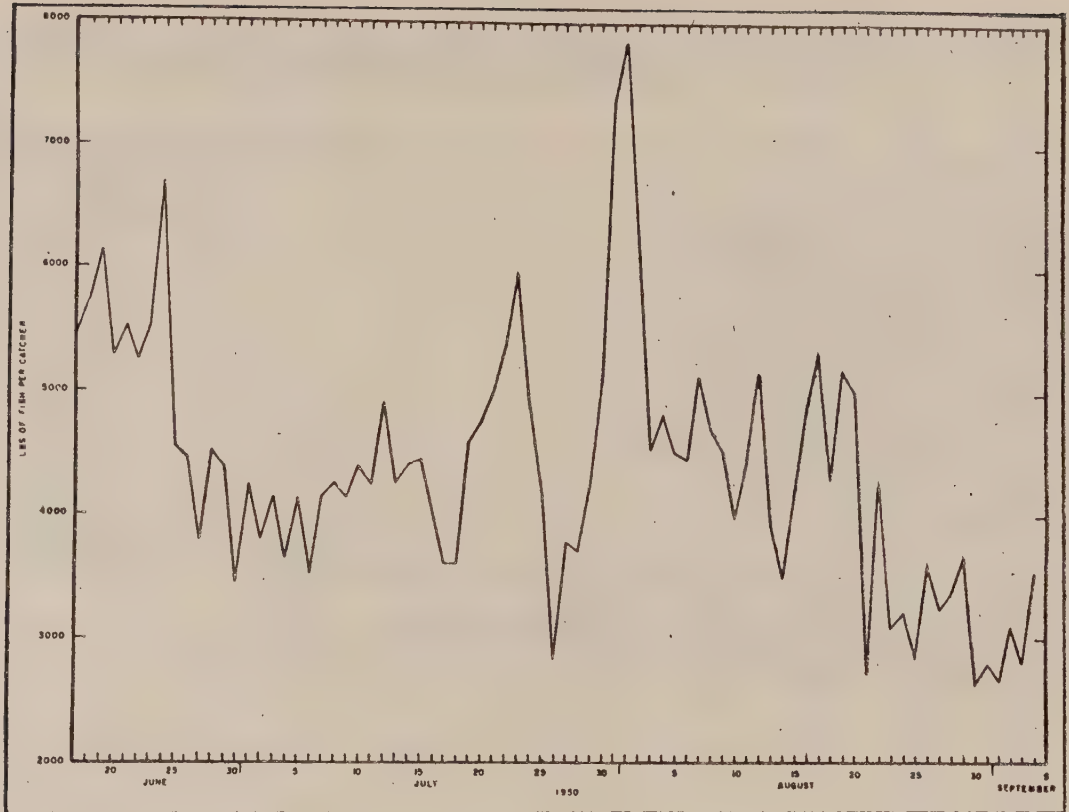


Figure 63.—Average catch of fish per day per catcher based on daily reported landings (Shimada, 1951).

of fishing of the six tuna mother ship expeditions between June 1950 and June 1951. Ego and Otsu (1952) published data from six expeditions and these are given in Table 34. Table 35 shows that the catch rates among the six expeditions did not vary by much. The first expedition achieved the lowest catch rate for all species with 3.85/100 hooks whereas the third recorded the highest of 4.76/100 hooks (Ego and Otsu, 1952). Van Campen (1952), reporting on three subsequent expeditions, found catch rates of 4.47 in the seventh, 4.04 in the eighth, and 3.55 in the ninth (Table 36). The overall average of all species for the nine expeditions was 4.10/100 hooks (Table 37).

Murphy and Otsu (1954) analyzed the catches of the nine tuna mother ship expeditions and the results indicated that yellowfin tuna were most abundant between the equator and lat. 4°N whereas the abundance of bigeye tuna and black marlin appeared to increase north of lat. 4°N . Examination of temperature sections revealed no signs of upwelling as contrasted with the central Pacific; however, the relative distribution of yellowfin tuna latitudinally in the western Pacific was similar to that in the central Pacific. On the other hand, the absolute level of the population of yellowfin tuna was higher in the central Pacific in 1951 than in the western Pacific in 1950-51.

The similarity in the relative latitudinal distribution of yellowfin tuna in the central and western Pacific suggested a possible conflict with the upwelling-plankton-forage tuna cycle proposed for the central Pacific by Murphy and Shomura (1953). Murphy and Otsu (1954), however, suggested that this conflict may not be real and that there may be upwelling in the western Pacific during some months and during some years as suggested by Mao and Yoshida (1955). An integration of average conditions rather than the momentary ecological situation measured by hydrographical and biological data may also be responsible for the distribution pattern of yellowfin tuna. Murphy and Otsu also suggested the possibility that peculiar ecological conditions near the equator favor yellowfin tuna at the expense of other fishes with or without upwelling. Slight or occasional upwelling superimposed on this background may have permitted the expansion of the yellowfin tuna population.

Nakamura (1951) dealt with fishing conditions for subsurface tunas and spearfishes in waters of the former mandated islands in considerable detail. Among his findings was that there were conspicuous differences in fishing conditions in different parts of this region. Table 38 shows that in the area south of lat. 5°N , which comes under the influence of the Equatorial Countercurrent, yellowfin tuna were distributed very densely, whereas north of lat. 5°N or in the region of the North Equatorial Current, their density fell off very sharply. Nakamura concluded that this region has superior grounds for longline fishing. Changes in fishing conditions accompanied changes in season, but these changes were comparatively slight, indicating generally stabilized fishing grounds.

Table 34.--Japanese tuna mother ship expeditions, catches and average weights (in pounds), by species (Ego and Otsu, 1952).

Species	E X P E D I T I O N S											
	First		Second		Third		Fourth		Fifth		Sixth	
	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.
Yellowfin tuna	4,572,698	75	3,246,486	101	395,889	67	805,609	78	2,362,692	74	710,739	75
Big-eyed tuna	698,761	80	396,913	98	58,279	90	138,979	96	863,066	86	158,597	98
Albacore	65,355	45	24,223	48	8,027	42	10,015	46	11,706	48	888	36
Black tuna	3,428	343	-	-	-	-	-	-	727	364	-	-
Skipjack tuna	6,966	8	16,671	12	1,234	9	502	7	835	10	2,540	7
Black marlin	1,759,751	131	1,447,517	149	72,609	117	295,098	132	658,987	131	211,412	125
White marlin	48,164	171	2,486	166	5,493	172	7,966	150	20,932	146	2,273	126
Sailfish	28,150	44	11,901	32	3,156	40	8,605	37	35,002	37	10,818	39
Swordfish	13,651	76	6,308	91	3,656	58	2,363	98	11,640	85	3,576	102
Striped marlin	1,228	123	1,605	123	190	80	231	116	521	87	370	123
Sharks	894,698	56	402,518	72	37,025	94	28,917	73	385,738	66	41,746	69
Others ^{2/}	23,045	28	21,298	29	4,095	18	12,234	23	23,396	19	16,604	23
Total	8,115,895		5,577,926		589,653		1,310,519		4,375,244		1,159,563	

1/ INCLUDES SHORT-NOSED SPEARFISH (TETRAPTERUS BREVIROSTRIS).

2/ INCLUDES MISCELLANEOUS SPECIES, SUCH AS WAHOO, DOLPHIN, AND BARRACUDA.

Table 35.--Catch rates of Japanese tuna mother ship expeditions (Ego and Otsu, 1952).

Species	NUMBER OF FISH CAUGHT PER 100 HOOKS PER DAY FISHED					
	E X P E D I T I O N					
	First	Second	Third	Fourth	Fifth	Sixth
Yellowfin tuna	2.28	2.50	3.38	2.71	2.24	2.49
Big-eyed tuna	0.33	0.32	0.37	0.38	0.70	0.43
Albacore	0.05	0.04	0.11	0.06	0.02	<0.01
Black tuna	<0.01	-	-	-	<0.01	-
Skipjack tuna	0.03	0.11	0.08	0.02	<0.01	0.09
Black marlin	0.50	0.76	0.36	0.59	0.35	0.45
White marlin	0.01	0.01	0.02	0.01	0.01	<0.01
Sailfish and Shortnosed spearfish	0.02	0.03	0.04	0.06	0.07	0.07
Broadbill swordfish	<0.01	0.01	0.04	0.01	0.01	<0.01
Striped marlin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sharks	0.60	0.44	0.23	0.10	0.41	0.16
Others	0.03	0.06	0.13	0.14	0.08	0.19
Tunas and marlins	3.23	3.77	4.40	3.84	3.40	3.55
Total	3.85	4.27	4.76	4.08	3.89	3.89

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Table 36.--Essential data on the seventh, eighth, and ninth Japanese tuna mother ship expeditions (Van Campen, 1952).

	E X P E D I T I O N		
	Seventh	Eighth	Ninth
Managing concern	Nippon Suisan K. K.	Taiyo Gyogyo K. K.	Nansei Suisan K. K.
Mothership	<u>Settsu Maru</u> (9,329 tons)	<u>Tenyo Maru No. 2</u> (10,620 tons)	<u>Tenryu Maru</u> (577 tons)
Number of catchers	26 (and 2 boats)	25 (and 1 boat)	3 (and 2 boats)
Left port	May 31, 1951	July 30, 1951	September 3, 1951
Returned to port	September 5, 1951	November 4, 1951	November 1, 1951
Fishing began	June 5, 1951	August 2, 1951	September 17, 1951
Fishing ended	August 26, 1951	October 24, 1951	October 20, 1951
Area fished	1° - 13° N. lat. 153° - 179° E. long.	1° - 13° N. lat. 151° - 179° E. long.	1° - 10° N. lat. 162° - 179° E. long.
Tuna catch	6,228,286 lbs.	4,348,407 lbs.	326,276 lbs.
Spearfish catch	2,149,787 lbs.	1,526,229 lbs.	173,042 lbs.
Sharks and miscellaneous	854,341 lbs.	1,173,497 lbs.	23,404 lbs.
Total catch	9,232,414 lbs.	7,048,133 lbs.	522,722 lbs.
Total boat/days fished	1,312	1,219	126
Average catch rate (fish per 100 hooks per day)	4.47	4.04	3.55

Table 37.--Catch rates by the seventh, eighth, and ninth Japanese tuna mother ship expeditions (Van Campen, 1952).

Species	Number of Fish Caught Per 100 Hooks Per Day Fished			
	Expedition			Average For Expeditions 1 Through 9
	7th	8th	9th	
Yellowfin tuna ..	2.09	1.64	1.40	2.14
Big-eyed tuna ...	0.93	0.80	0.88	0.62
Albacore	0.06	0.16	0.10	0.07
Black tuna	<0.01	<0.01	<0.01	<0.01
Skipjack tuna ...	0.07	0.06	0.08	0.05
Black marlin	0.60	0.48	0.75	0.53
White marlin	<0.01	<0.01	<0.01	<0.01
Sailfish and short-nosed spearfish	0.04	0.04	0.03	0.04
Broadbill swordfish	<0.01	<0.01	<0.01	<0.01
Striped marlin ..	<0.01	<0.01	<0.01	<0.01
Sharks	0.57	0.75	0.14	0.54
Others	0.09	0.10	0.16	0.08
Total	4.47	4.04	3.55	4.10
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Table 38.--Comparison of fishing conditions on either side of lat. 5°N (Nakamura, 1951).

Area	Number of hooks	Yellowfin		Bigeye		Spearfishes		Total	
		Number of fish	Catch rate	Number of fish	Catch rate	Number of fish	Catch rate	Number of fish	Catch rate
0° - 5° N.	417,851	16,706	3.99	2,059	0.49	2,928	0.70	21,819	5.22
5° -10° N.	229,838	5,022	2.19	1,226	0.53	1,824	0.79	8,088	3.52

Note: Longitude is not taken into consideration in this table.

Table 39.--Catches, in thousand metric tons, of spearfishes and tunas from the western central Pacific Ocean (D. W. Hagborg, FAO, Rome, pers. commun.)

	1966	1967	1968	1969	1970	1971	1972
Pacific striped marlin	1.9	1.7	1.2	0.9	1.3	0.7	0.8
Indo-Pacific sailfish	1.2	1.4	0.4	0.3	0.3	0.5	0.6
Black/Indo-Pacific blue marlin	6.3	4.5	4.1	3.8	4.5	4.5	4.6
Broadbill swordfish	0.9	1.0	2.3	1.8	1.4	0.9	0.6
Bluefin tuna	1.0	0.5	0.5	0.3	0.2	0.0	0.0
Yellowfin tuna	37.8	21.0	20.4	22.1	19.3	24.7	23.8
Albacore	14.3	9.2	7.8	5.8	8.9	1.6	2.1
Bigeye tuna	17.0	16.3	12.4	12.9	12.4	11.5	19.6

The subsequent development of the longline fishing grounds not only in the western central Pacific but also in the central and eastern Pacific resulted from the lifting of restrictions imposed immediately after the war. According to Nippon Suisan Shimbun (1953), the SCAP fishing area, also called the MacArthur Line, severely restricted the operating radius of the Japanese longliners. But on 25 April 1952, the MacArthur Line was removed so that Japanese vessels were no longer restricted. International complications with Korea and Communist China followed and the result was that the Japanese vessels could not operate freely in Korean waters, the East China Sea, and the Yellow Sea. Furthermore, the North Pacific fisheries was also markedly restricted. Thus, the Japanese longliners spread southward into Micronesian waters and the South Pacific, and eastward into the central and eastern Pacific.

The eastward expansion of the Japanese longline fishing effort after 1952 was reported by Rothschild (1966a). He showed that effort tended to be concentrated off Japan in the western Pacific in the early 1950's, tended more toward the central Pacific in the mid-1950's, and was largely concentrated at the longitude of Baja California in the southwestern Pacific by the early 1960's (Figure 64). By latitude, the expansion went from the North Pacific in 1953 to the South Pacific by 1963. Table 39 shows the catches of tunas (except skipjack tuna) and spearfishes from the western central Pacific.

DEVELOPMENTAL POTENTIAL

In a study of the tuna resources of the oceanic regions of the Pacific Ocean, Rothschild and Uchida (1968) found increasing longline effort correlated with changes in apparent abundance, average size, and total catch for the three most important species of tuna--yellowfin tuna, bigeye tuna, and albacore--that are taken on the longline gear. With the exception of the South Pacific albacore, all three species showed declines in apparent abundance and a leveling or stabilization of total catch. They concluded on the basis of this qualitative examination that with the present method of fishing (with respect to gear, the size of fish that the gear selects, and the distribution and intensity of effort) substantial increases in the catches of yellowfin tuna, bigeye tuna, and albacore in the Pacific are unlikely.

Skipjack tuna, on the other hand, has an exploitation status that is different from the other subsurface tunas that are taken commercially (Rothschild and Uchida, 1968). Whereas yellowfin tuna, bigeye tuna, and albacore all show the effects of exploitation, there

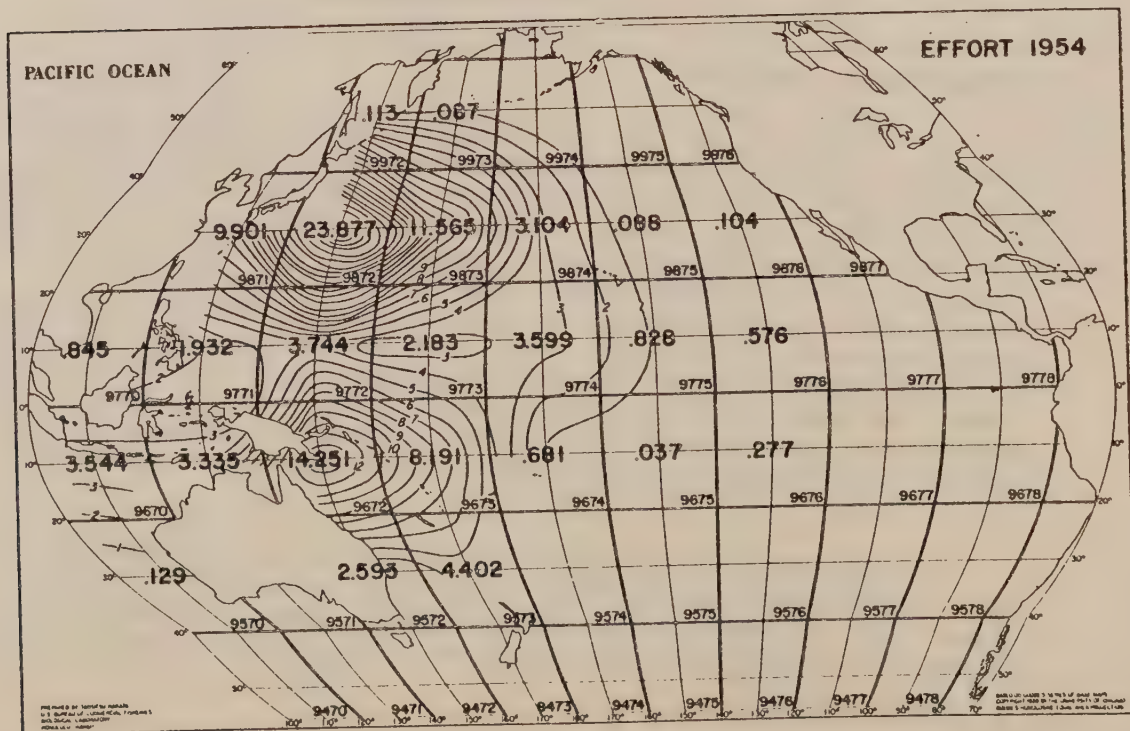
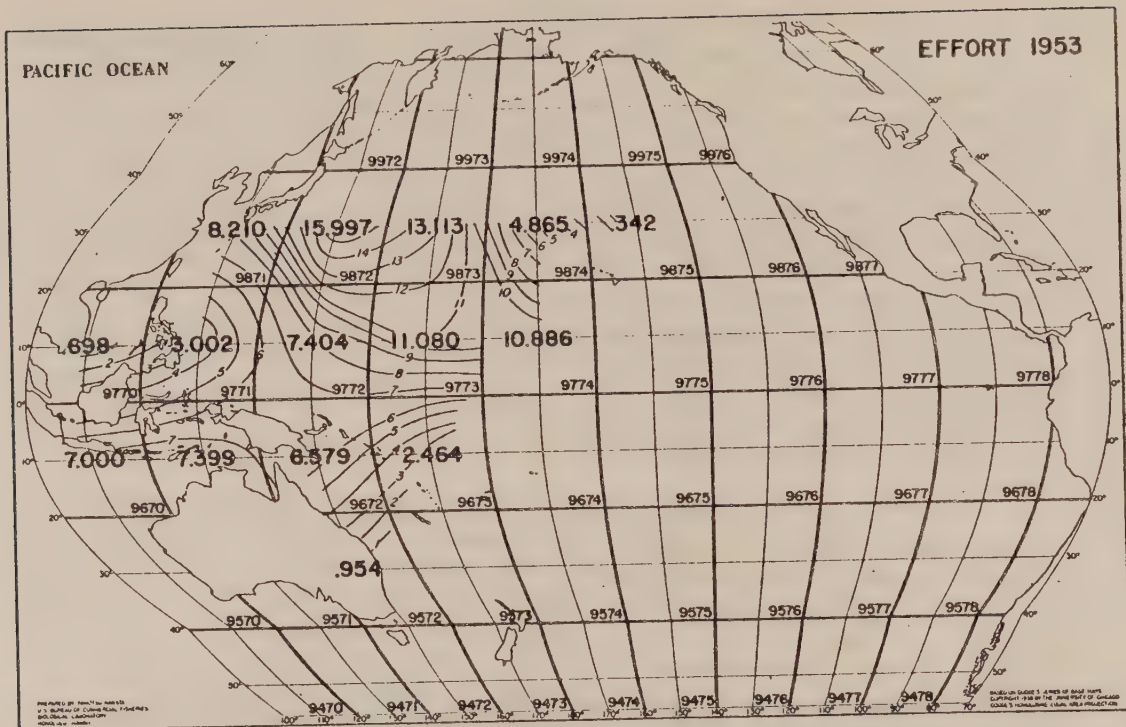


Figure 64.--Percentage of reported total annual effort (numbers of hooks) expended in each 20° quadrangle (Rothschild, 1966a).

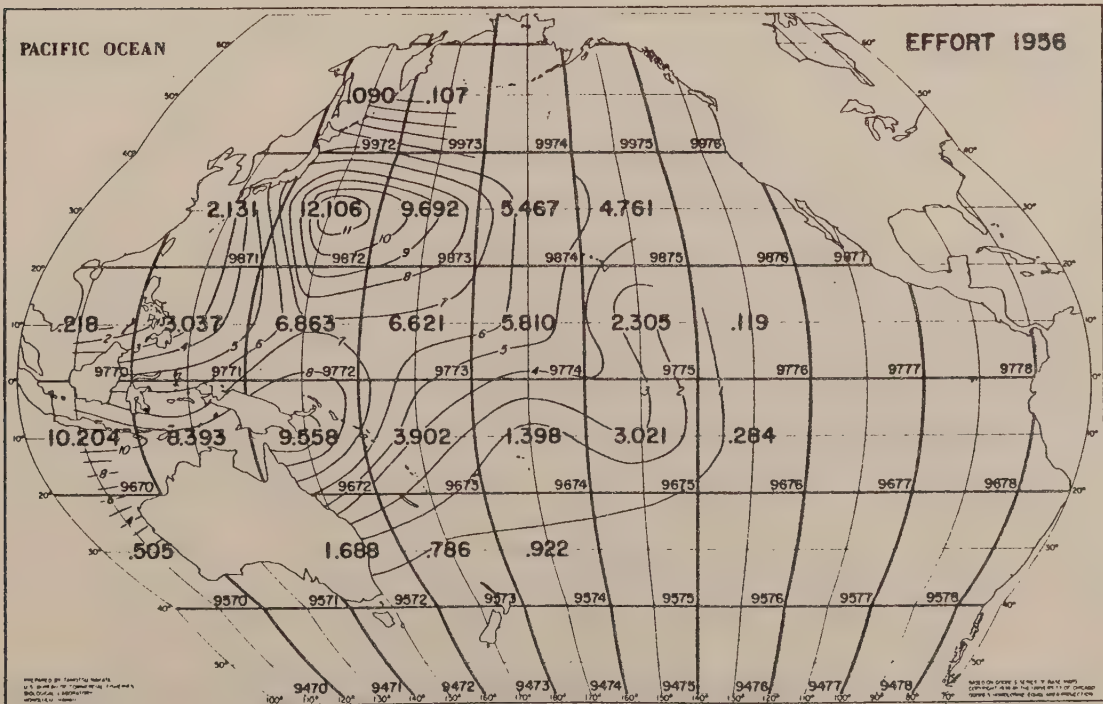
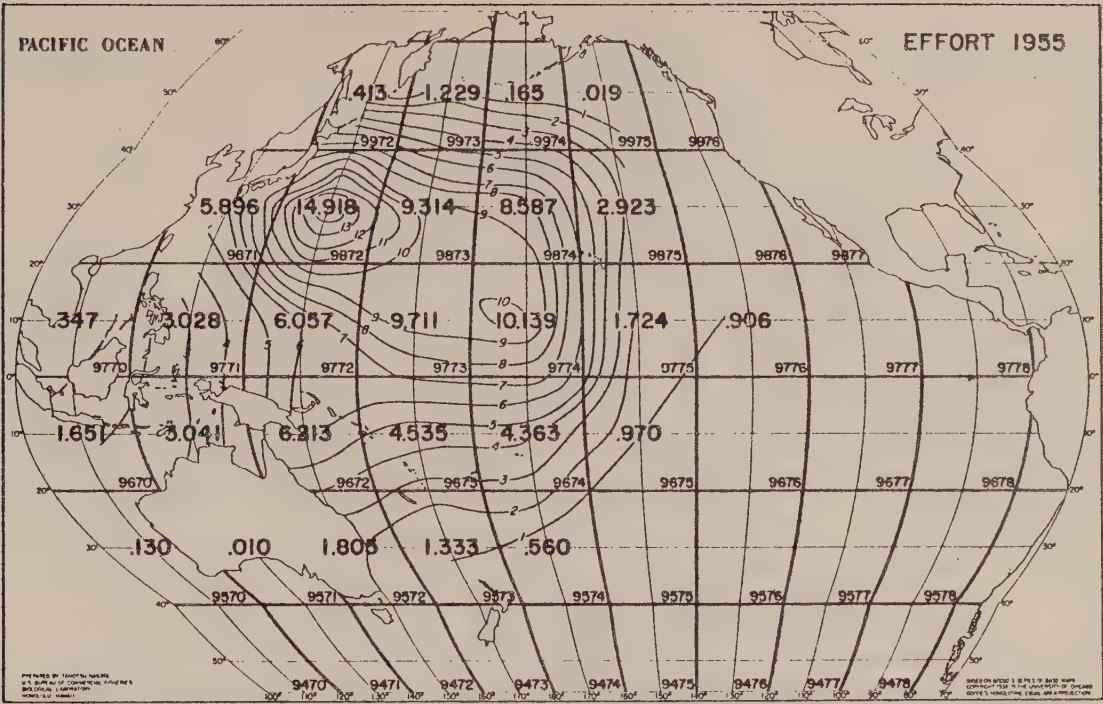


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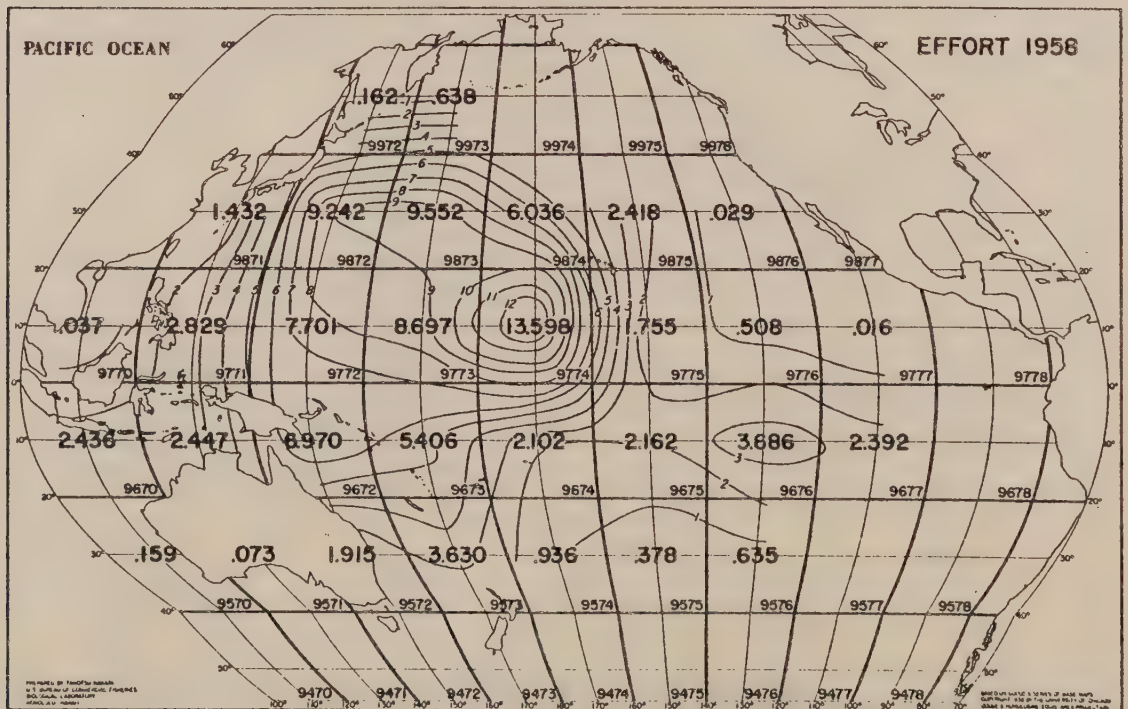


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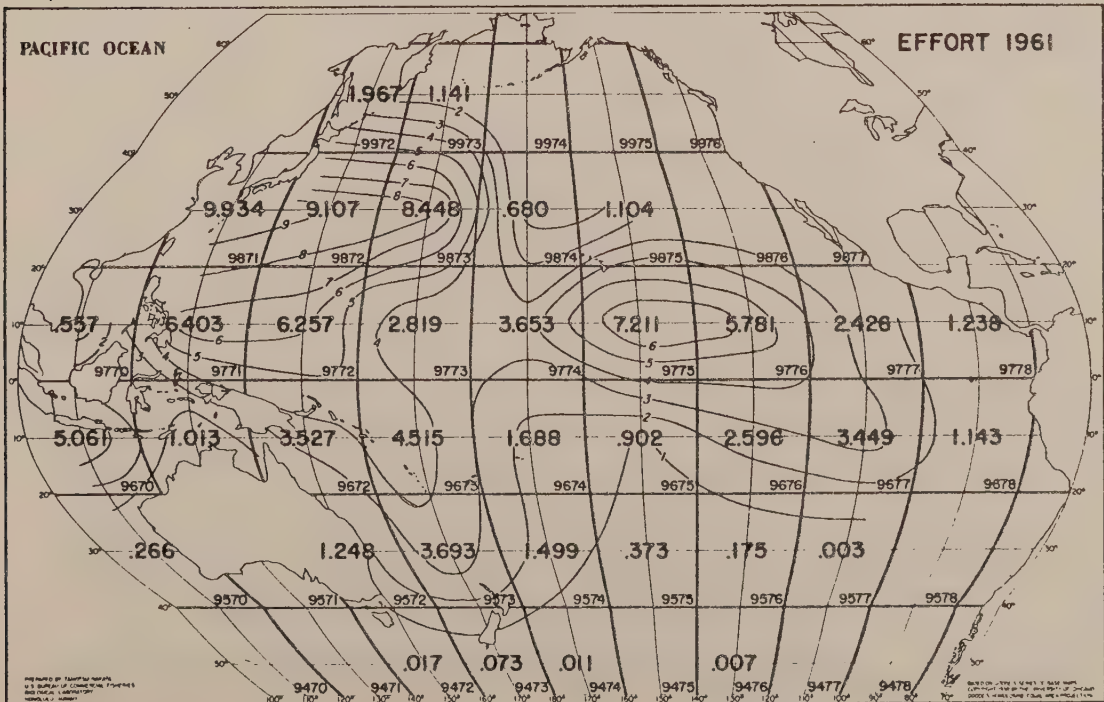
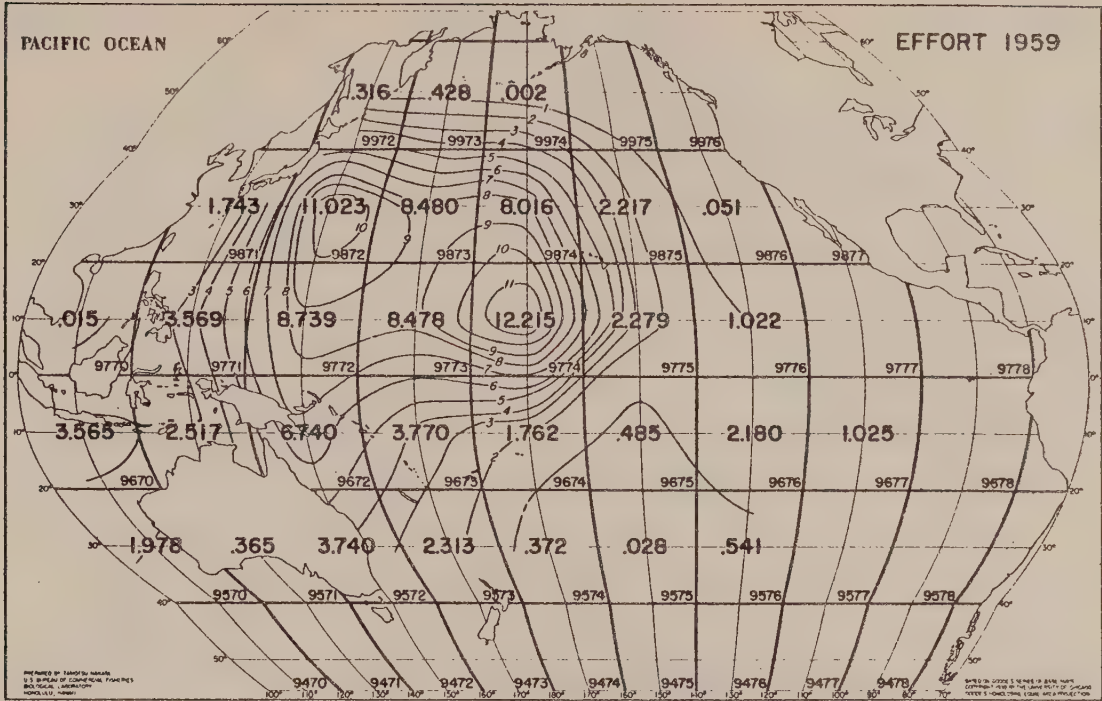


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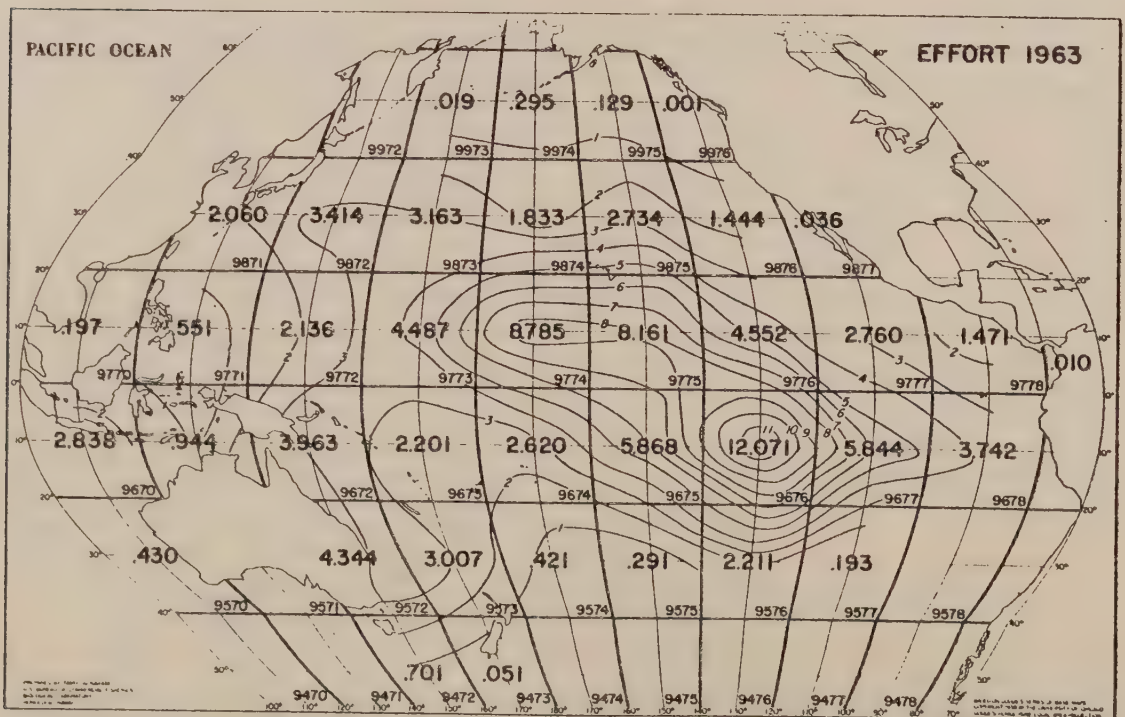
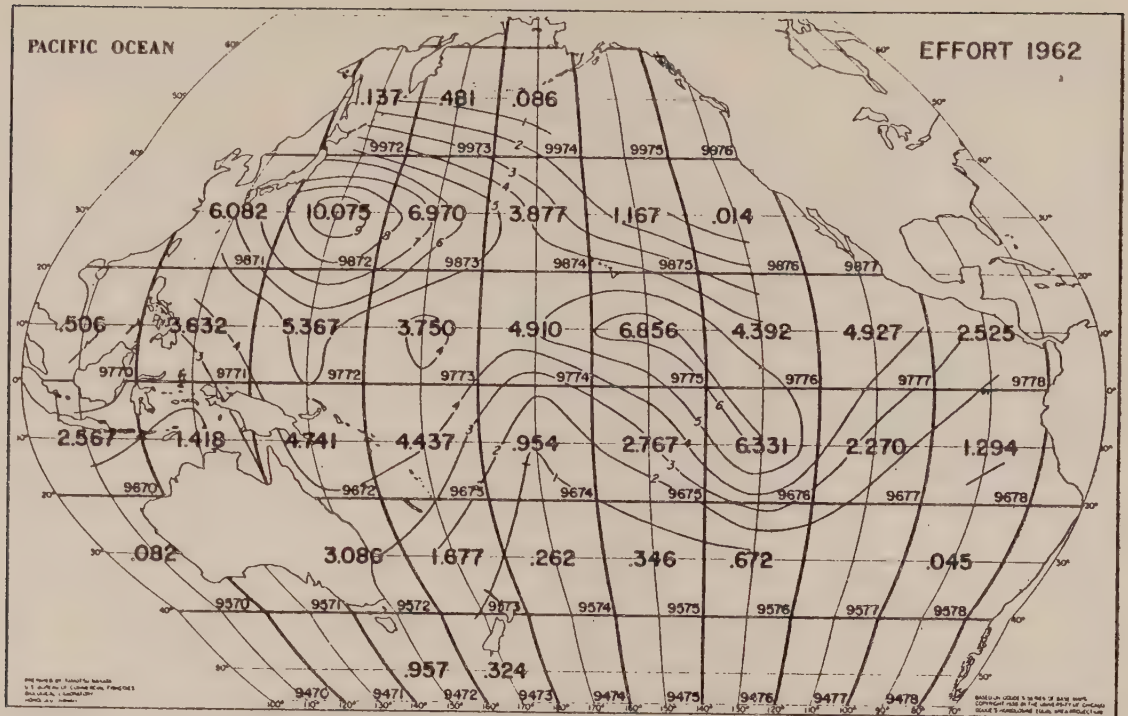


Figure 64.--Continued.

is no evidence in the literature that fishing has had any measurable effect on the stocks. This observation, that there are no observable effects of fishing on the established fisheries in Japan or the coasts of the Americas and that there is sizable potential skipjack tuna yield, has induced the tuna-producing nations to turn to this species for increased production.

The constraints on harvesting skipjack tuna mostly involve our ignorance or uncertainty about their potentials and about more efficient ways of capturing them. We have seen earlier that the major effort in the tremendous expansion of skipjack tuna fishing has come from the Japanese in the western Pacific in waters surrounding the island groups of Micronesia. There is, however, growing interest within the United States tuna fishing industry in the development of resources in areas such as Micronesia.

In developing their southern water fishery, the Japanese have been active not only in research to keep baitfish alive longer, but also in attempting to locate new sources of bait close to the fishing grounds. By 1971, Japanese firms were actively pursuing the establishment of joint skipjack tuna fishing ventures in Micronesia. Two Japanese firms negotiated an agreement with a Trukese businessman and began fishing out of Truk with two pole-and-line vessels in the 20- and 25-GT class accompanied by one mother ship (U.S. NMFS, 1971a). At Ponape, two other Japanese firms jointly negotiated an agreement with the local government and began operations with one mother ship and three 30-ton pole-and-line vessels. Fishing reportedly began in late July 1971. Soon afterwards, a third Japanese firm proposed still another joint venture in Ponape (U.S. NMFS, 1971b). In early 1972, a five-man Japanese team, dispatched by another Japanese firm to survey Ponape's baitfish resources, found the outlook for skipjack tuna fishery development very favorable (U.S. NMFS, 1972). The Ponape District Fishery Corporation agreed to a joint-venture agreement under which four 39-GT skipjack tuna vessels and one 1,000-GT refrigerated mother ship began fishing in June 1972. Future plans also included the construction of a cold storage and processing plant at Ponape.

Bait surveys have also been made on several of the other islands and atolls in the Trust Territory. Wilson (1971) reported on a bait survey of Truk lagoon. Among those species that could be used for live-bait fishing were snapper, Gymnoaesio argenteus; cardinalfish, Rhabdamia cypselurus; sardine, Herklotsichthys punctatus; round herring, Spratelloides delicatulus and S. gracilis; silversides, Allanetta ovalaua and Pranesus pinguis; and damselfish, Pomacentrus pavo. Townsend Cromwell, an NMFS research vessel dispatched from Honolulu, surveyed islands to the south and west of Truk but found no substantial amounts of bait except round herring, S. delicatulus, which, as bait, are weak and do not survive long in baitwells (Hida, 1971). Also observed along the shoreline were small goatfish, mostly Mulloidichthys

samoensis; jack, Caranx spp.; cardinalfish, Apogonidae; bananafish, Caesionidae; silverside, Atherinidae; damselfish, Pomacentridae; and anchovy, Stolephorus indicus.

In the Marshalls, Cromwell surveyed Majuro and Jaluit atolls and found large concentrations of sardines, Herklotsichthys sp. and possibly Sardinella sp. in both areas. An NMFS-chartered fishing vessel, Anela, fishing out of Honolulu, confirmed that there were large concentrations of bait at Majuro and Jaluit (Uchida and Sumida, 1973). Anela exploring the possibility of developing commercial pole-and-line fisheries for skipjack tuna in the Marshalls and American Samoa, found good concentrations of both silverside, P. pinguis, and sardine, H. punctatus. At Majuro, Anela caught 205 buckets in five sets or 41 buckets per set whereas at Jaluit she caught 189 buckets in two sets or 94.5 buckets per set.

Subsequent investigations of bait resources in the Marshalls, however, indicated that distribution and apparent abundance of baitfish such as silversides and sardines varied considerably. Hida and Uchiyama (MS),³ reporting on the results of quarterly field trips to sample and observe concentrations of baitfish in Majuro lagoon, discovered that from November 1972 through May 1973, there were no signs of any baitfish in the lagoon. In April 1974, reports from an observer aboard a fishing vessel conducting experimental fishing in the Marshalls indicated that silversides and sardines were again present in large concentrations in the lagoon.

Turning to the Western Carolines, there appears to be some doubt that the pole-and-line fleet in Palau could be expanded much beyond 12 vessels. Muller (MS),² who studied the population of Stolephorus heterolobus from Palau, concluded that the bait fishery in Palau is operating at the optimum level for the main baiting area. He speculated that if bait catches are at their maximum sustainable level, then the vessels will need to switch from 1-day to multi-day trips in order for the fishery to expand. Fleet size can be doubled without increasing fishing pressure on the bait by baiting every other day. From the industry's standpoint multi-day trips are desirable; lost time due to traveling to and from the baiting and fishing grounds, and baiting time will be reduced whereas fishing time would increase. More conservative use of bait would also help to extend the Palau bait supply.

A 190-GT skipjack tuna vessel, Akitsu Maru No. 20, surveyed waters around Ponape from 5 August to 2 October 1974 (Japan Marine Fishery Resource Research Center, 1975; Otsu, in press). Briefly, the survey showed the following:

³Hida, T. S., and J. H. Uchiyama. Baitfish study in Majuro, Marshall Islands. Draft report distributed for information in connection with Tuna Baitfish Workshop, 4-6 June 1974, Honolulu, HI 96812.

1. Anchovies, 200 buckets of which were loaded aboard the vessel at Tateyama port of Chiba Prefecture, suffered mortalities of about 19% during the outgoing trip from Japan to the Caroline Islands.

2. In waters around Ponape, Akitsu Maru baited 79 times in 45 nights with a stick-held dip net, or an average of 1.8 times per night. Catching a total of 1,056 buckets (6.6 lb or 3 kg per bucket) or an average of 23.5 buckets per night, the vessel caught predominantly "tarekuchi," S. heterolobus (23.5%). Other species included S. indicus, Harengula ovalis, Allanetta forskali, Dussumieria hasseltii, Spratelloides delicatulus, Trachurops mauritianus, Decapterus sp., Caesio pisang, and Siganus sp.

3. Survival rate of "tarekuchi" in the baitwells was very poor with only a few lasting more than 12 h. Among the other species, T. mauritianus and Siganus sp. were the most durable in the baitwells.

4. Near the Bonin Islands, the vessel landed about 8.8 ST (8 MT) in 8 days of fishing or 1.1 ST (1 MT) per day. Fish size varied between 3.7 and 14.1 lb (1.7 and 6.4 kg).

5. Around Ponape, the vessel fished with locally caught bait for 34 days and produced a catch of 37 ST (34 MT) of skipjack tuna and 335 lb (154 kg) of yellowfin tuna. Catch per day was about 1.1 ST (1 MT). Ten percent of the schools sighted were yellowfin tuna. The vessel usually operated within 10-30 mi (18.5-55.6 km) of Ponape because of poor bait survival. The survey also revealed that skipjack tuna schools around Ponape responded actively usually in the morning and late afternoon.

A recent report of baitfish being taken on the high seas has evoked considerable interest within the Japanese tuna fishing industry (Otsu, in press). No. 3 Inari Maru, a 299-GT skipjack tuna fishing vessel, reported capturing 50-60 buckets of "doku-uroko ibodai," Tetragonurus atlanticus, at night at lat. 3°51'N and long. 161°15'E. Using a 500-W lamp, Inari Maru caught the baitfish on the high seas roughly 180 mi (334 km) south of Ponape. With this bait, the vessel caught 11 ST (10 MT) of skipjack tuna. Since then, two other vessels have baited successfully in the same area.

Japanese researchers believe that these coal-black fish inhabit deep water. At a size of about 1.5-2.8 in. (4-7 cm) when captured, the ibodai showed several qualities of a good baitfish; they swam slowly at the surface when chummed, were readily taken by skipjack tuna, and survived at least up to 16 days in the baitwells. The Japanese reported that there is a need to study the abundance, distribution, and seasonality of this species. Not only the bait resource but also methods to improve bait survival have been under

investigation. After capture, baitfish are usually transferred from the net to the baitwells by scoops or buckets. Handling during the transfer is one of the major causes of baitfish mortality. To improve baitfish survival after capture, a naval architect of the Trust Territory Marine Resources Division, after consulting with fishermen and industry personnel, has designed a skipjack tuna pole-and-line fishing vessel around the baitwells (Pacific Islands Monthly, 1974). The unique features of this vessel, which will have a range of 1,500 mi (2,780 km), travel at 9 knots, and carry 14 crew members, are specially designed baitwells that will allow captured live bait to "swim" into them through underwater doors, thus eliminating the need to scoop or bucket the bait.

SIZE OF FISH

The size frequencies of the tunas can be used to detect areal and temporal changes in the fish population and also to describe the segment of the population that a particular fishing gear sampled. But technologically, a fisherman is interested in fish size, because he can use size data to estimate the numbers that need to be captured to achieve a particular tonnage. To a processor, knowledge of fish size provides a means of anticipating problems that may arise in processing fish from a particular area. In this section, all fish lengths reported in the literature have been converted to weight in pounds and kilograms.

BY LONGLINE.

Longline samples only the large mature tunas. In the western Pacific, Murphy and Otsu (1954) found that the bigeye tuna landed during the nine mother ship expeditions ranged widely from 3 to 292 lb (1.4 to 132 kg), but almost 90% were within 34 and 173 lb (15 and 78 kg) (Figure 65). Longitudinal differences are apparent in the size of bigeye tuna. Yukinawa (1958) found that larger fish were more commonly taken toward the east (Figure 66) and latitudinally those fish caught in lat. 6°-12°N were slightly larger than those taken further south in lat. 2°S-6°N.

Concerning yellowfin tuna, Murphy and Otsu (1954) found considerable variation from sample to sample, but it did not appear to be related to time or space. Figure 65 shows that yellowfin tuna ranged from 6 to 204 lb (2.7 to 93 kg), but 90% of the fish sampled were within a relatively narrow range between 45 and 124 lb (20 and 56 kg).

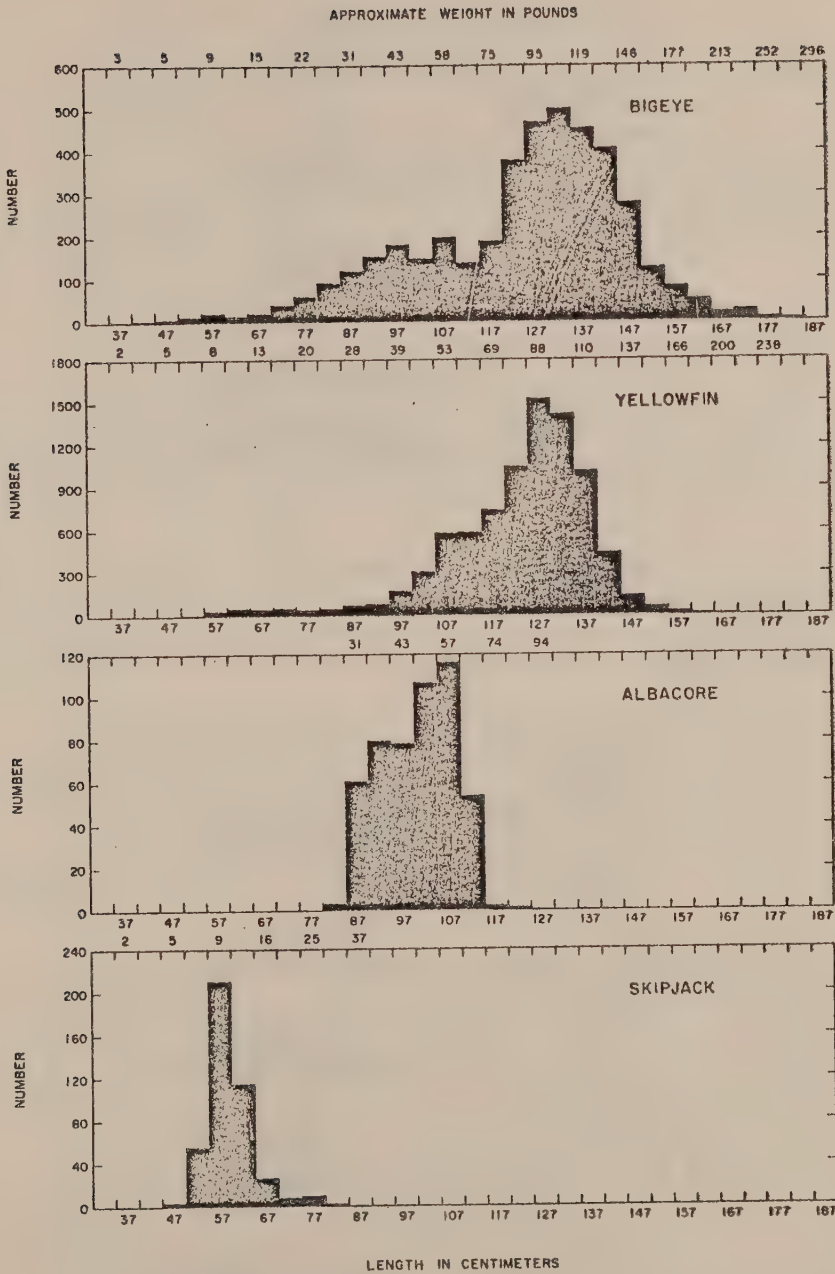


Figure 65.--Length frequencies of the four species of tuna commonly taken during the mother ship operations (Murphy and Otsu, 1954).

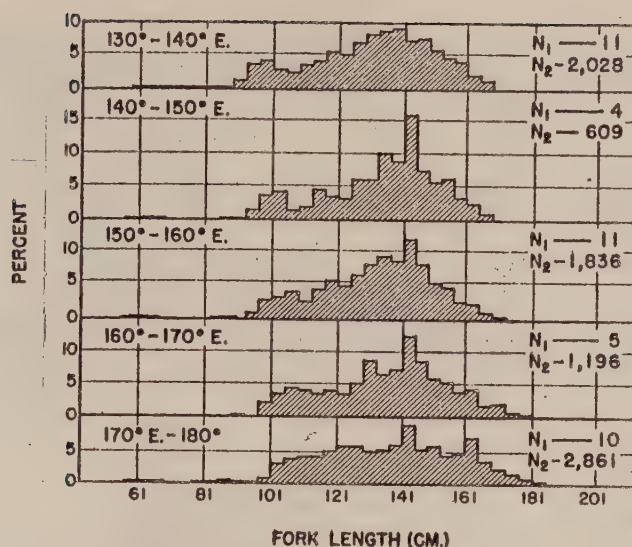


Figure 66.--Length-frequency distribution of bigeye tuna caught by Japanese longlines in 1954, for every 10° of longitude from 130°E to 180° along lat. 6°-12°N. N₁ is the number of samples and N₂ is the total number of fish (adapted from Yukinawa, 1958).

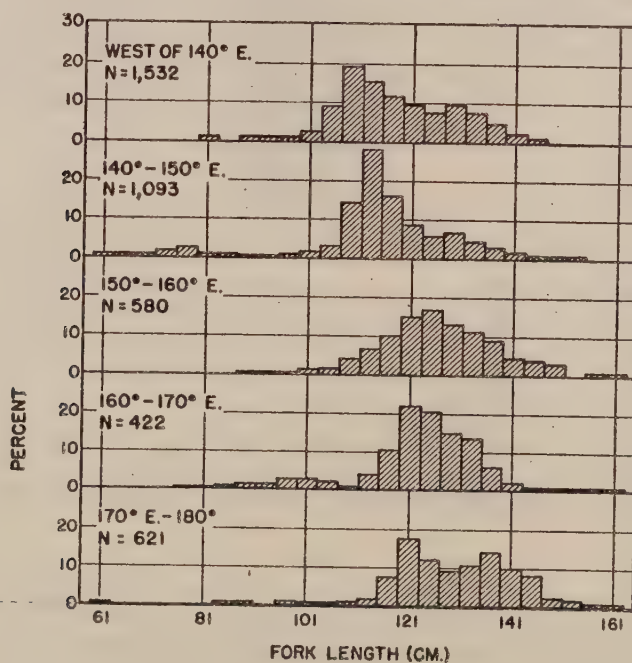


Figure 67.--Length-frequency distribution of yellowfin tuna taken by Japanese longlines, for every 10° of longitude from west of 140°E to 180° between lat. 2° and 8°N. Data for long. 160°-170°E were collected from October 1953 to March 1954 (based on Yabuta and Yukinawa, 1958).

Yabuta and Yukinawa (1958), who sampled longline-caught yellowfin tuna taken in waters of the Eastern Caroline Islands, reported that in the area bounded by lat. 12°N and 4°S between long. 150° and 170°E , size did not vary significantly from one current system to another (Figure 67). There was, however, a longitudinal gradient; the major modal group of fish taken west of long. 140°E was 55 lb (25 kg) compared to 112 lb (51 kg) for fish taken east of long. 180° .

Figure 65 also shows that albacore varied from 27 to 86 lb (12 to 39 kg) but the bulk of the catch consisted of fish from 29 to 63 lb (13 to 29 kg) (Murphy and Otsu, 1954). These fish are much larger than those taken by surface trolling off San Pedro, California where size usually varies between 10 and 35 lb (4.5 and 16 kg) (Brock, 1943). The skipjack tuna, according to Figure 65, varied from 5 to 30 lb (2.3 to 14 kg).

BY POLE AND LINE

The sizes of skipjack tuna taken by pole-and-line fishing have been well documented in several publications. The annual "Atlas of skipjack tuna fishing grounds in southern waters," published by the Tohoku Regional Fisheries Research Laboratory (undated a, b, c, d, e), gives a good description of the monthly changes in size composition of the fish caught by Japanese vessels in the western Pacific.

Briefly, the data from Tohoku Regional Fisheries Research Laboratory show that there are significant differences in skipjack tuna size in the various fishing grounds within the waters of Micronesia. For example, during the 1970 season, the Japanese skipjack tuna vessels encountered 7.7- to 9.2-lb (3.5- to 4.2-kg) fish at lat. 7° - 9°N , 6.8- to 7.7-lb (3.1- to 3.5-kg) fish in lat. 3° - 5°N , and 5.6- to 6.0-lb (2.5- to 2.7-kg) fish between lat. 2°N and 1°S (Figure 68). Thus, fish were usually smaller toward the equator and this size differentiation by latitude can be detected in size samples collected each year. Furthermore, in 1971, it became apparent that skipjack tuna sizes also differed in an east-west direction. Fishing in a wide expanse from west to east across Micronesia, the pole-and-line vessels in the Western Carolines caught largely medium-size skipjack tuna of about 8 lb (3.6 kg) and some small fish of about 3 lb (1.4 kg) throughout the season. On the other hand, the catches of vessels operating to the east around the Marshalls consisted predominantly of larger fish of about 10 lb (4.5 kg).

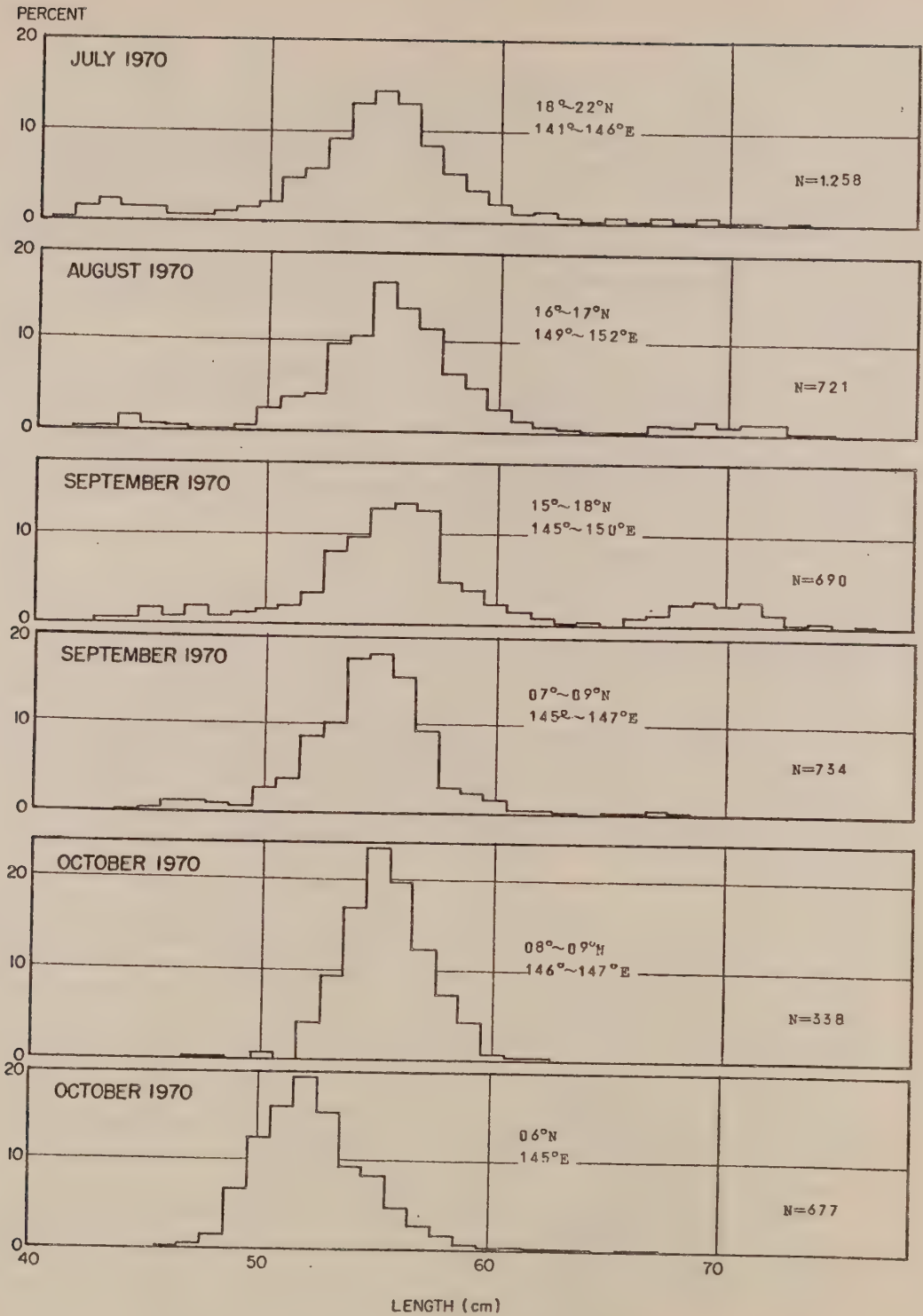


Figure 68.--Length-frequency distributions of skipjack tuna taken in southern waters (Tohoku Regional Fisheries Research Laboratory, undated d).

PERCENT

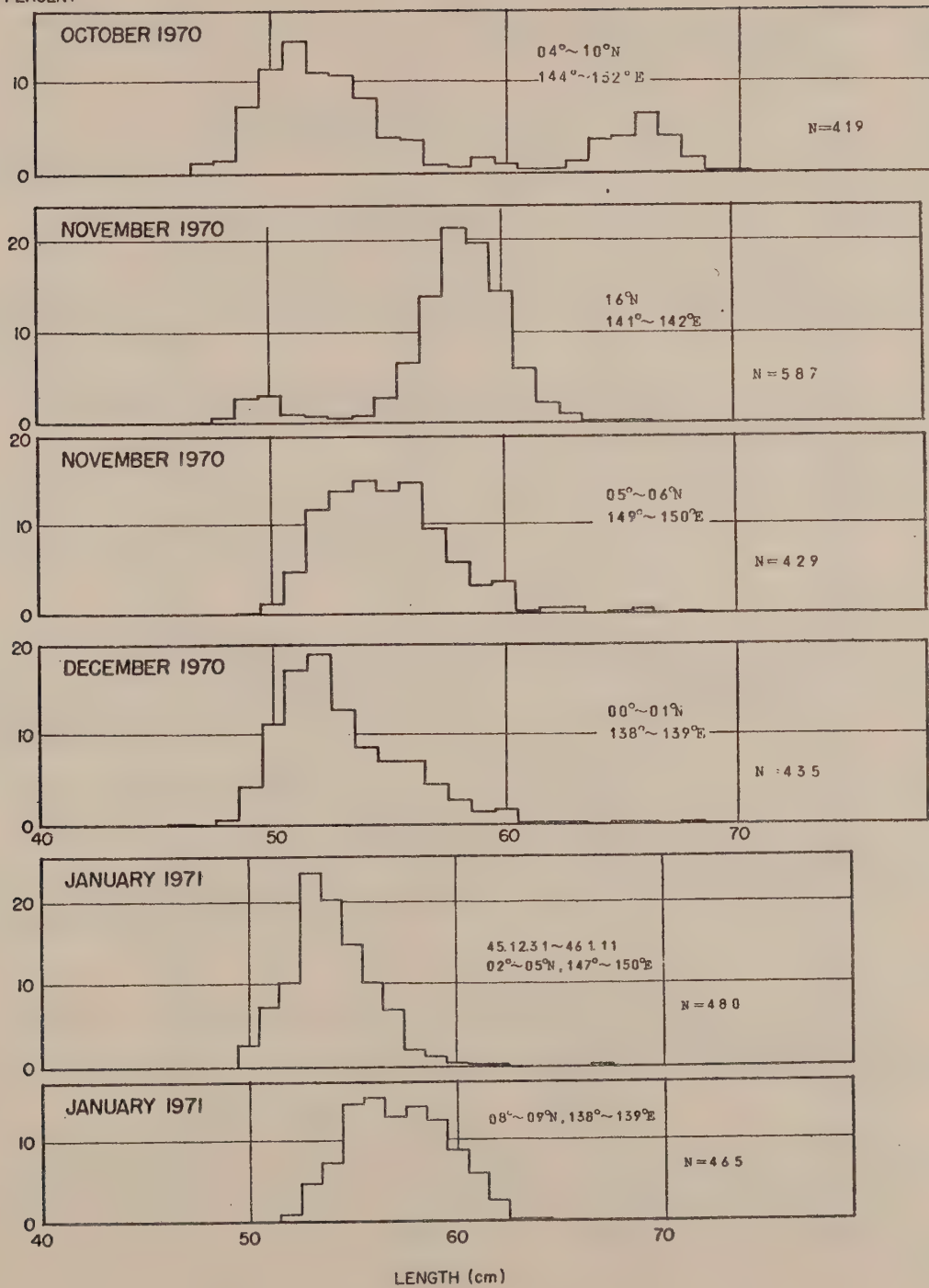


Figure 68.--Continued.

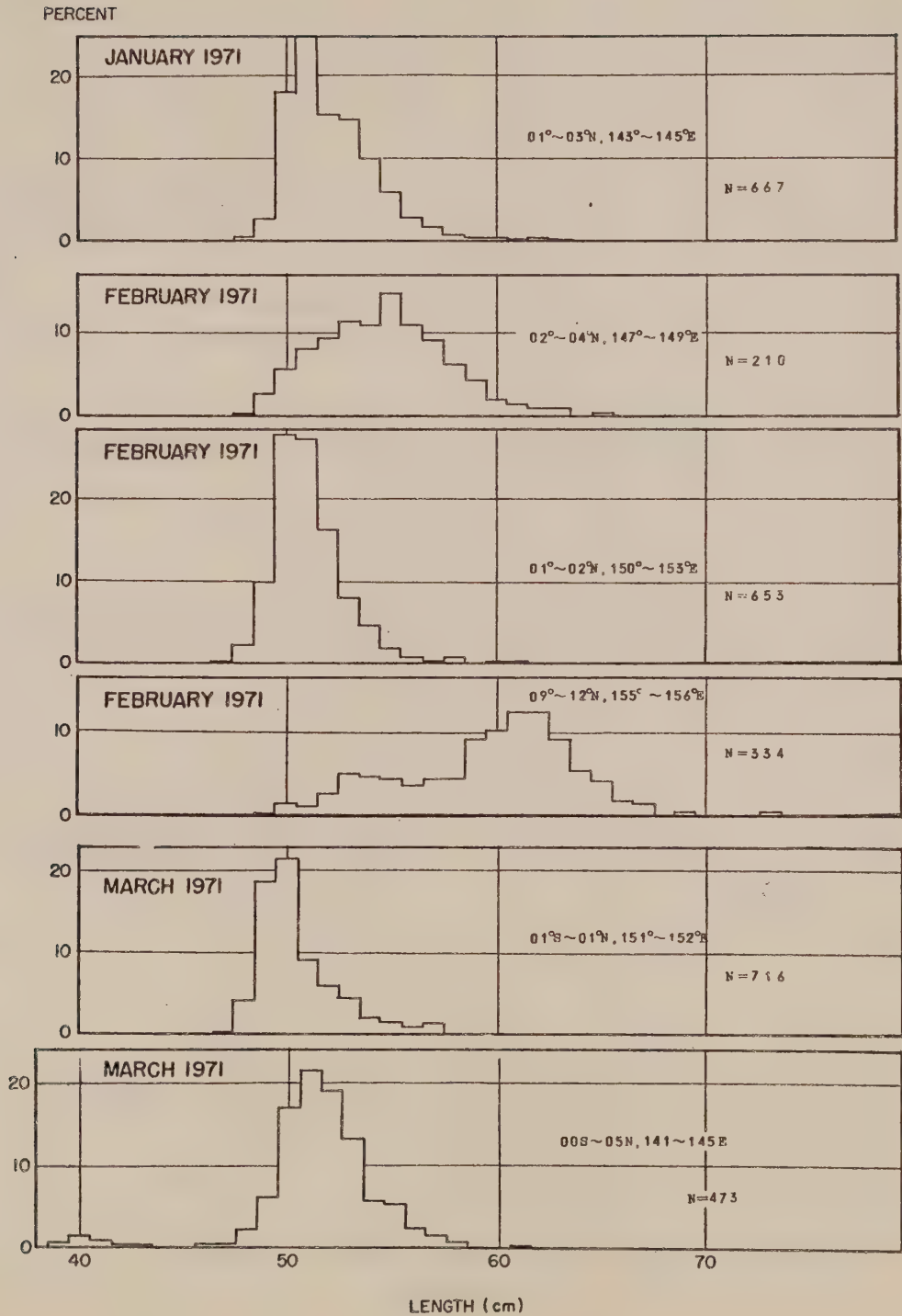


Figure 68.--Continued.

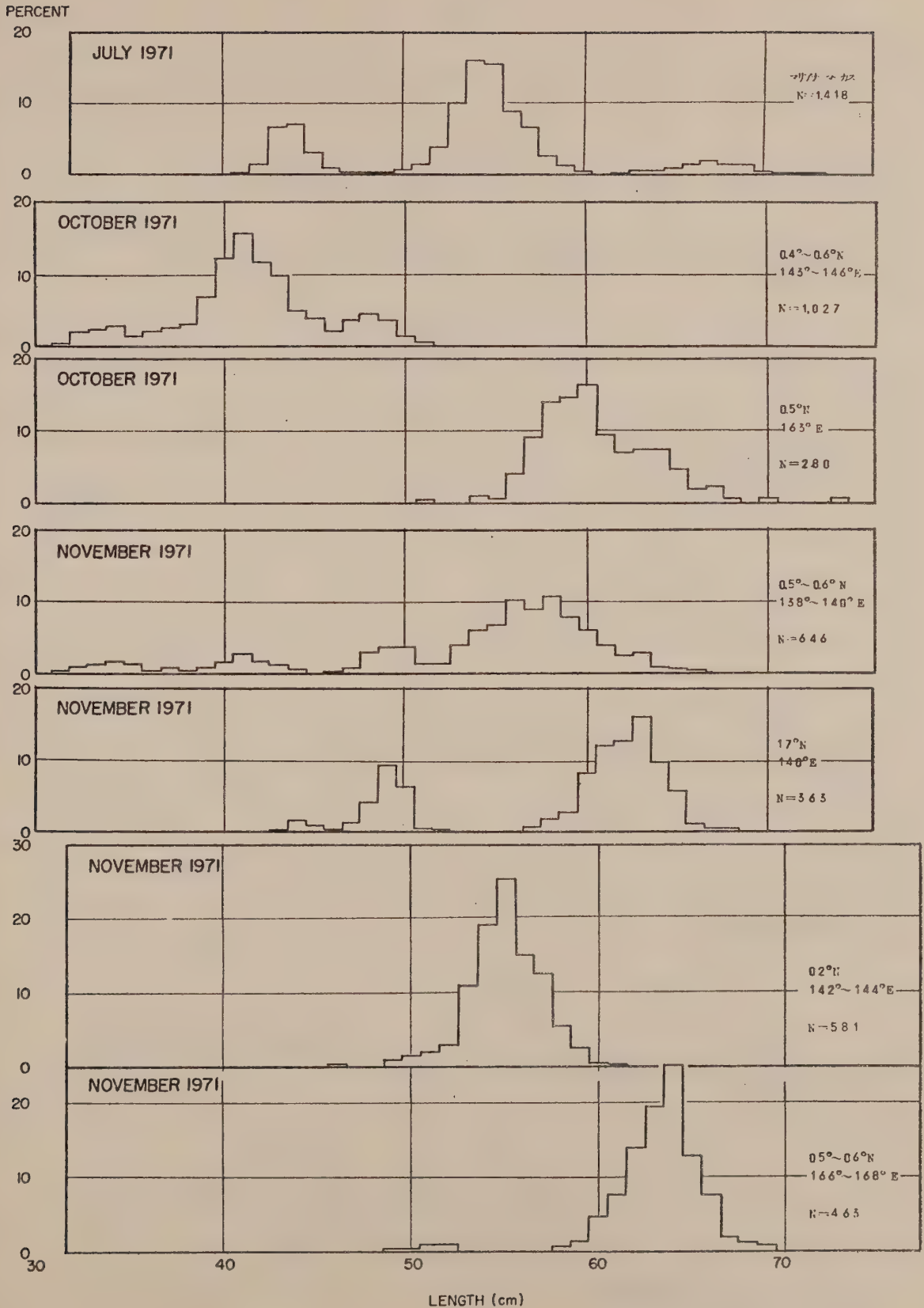


Figure 68.--Continued.

PERCENT

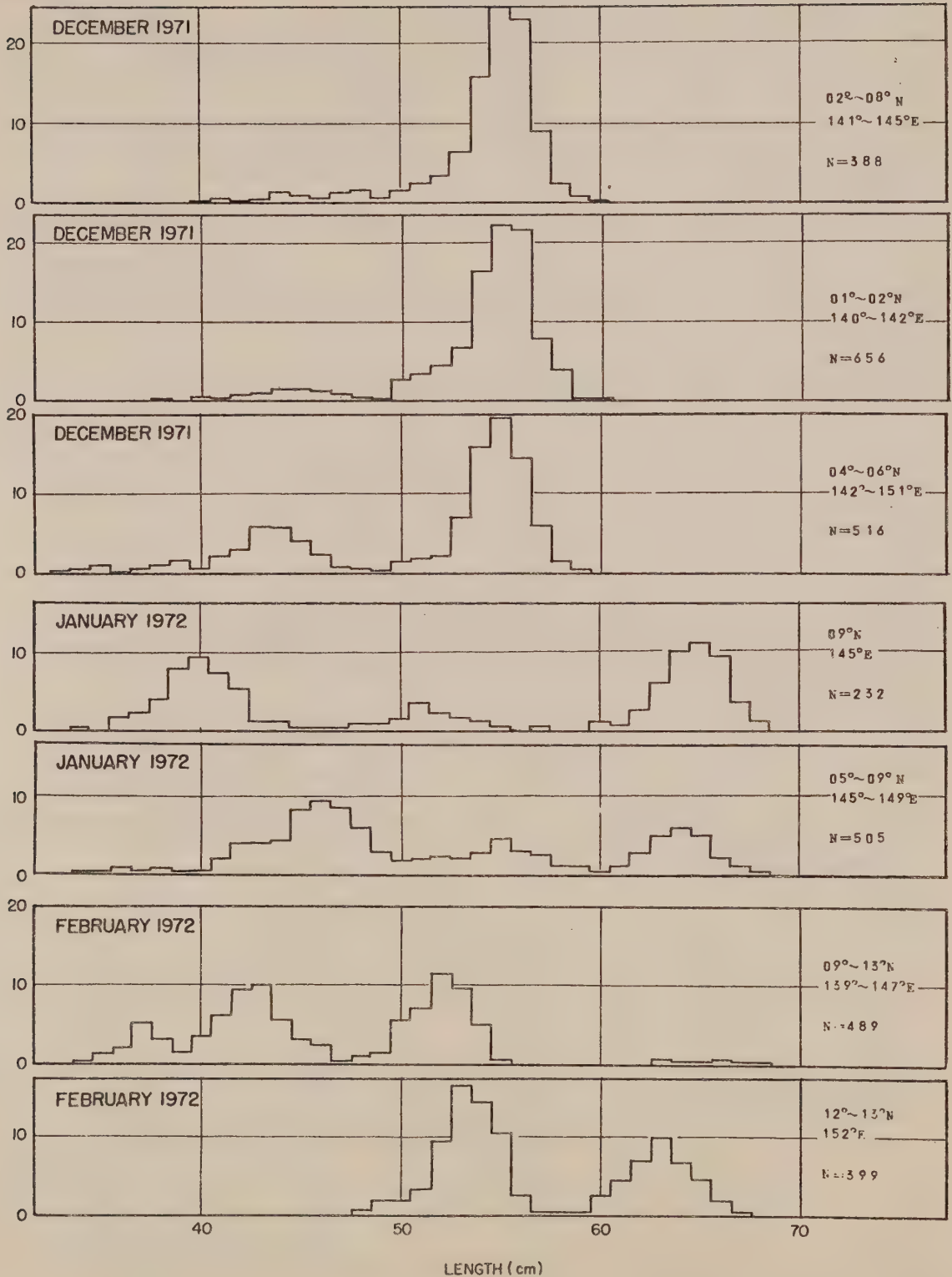


Figure 68.--Continued.

PERCENT

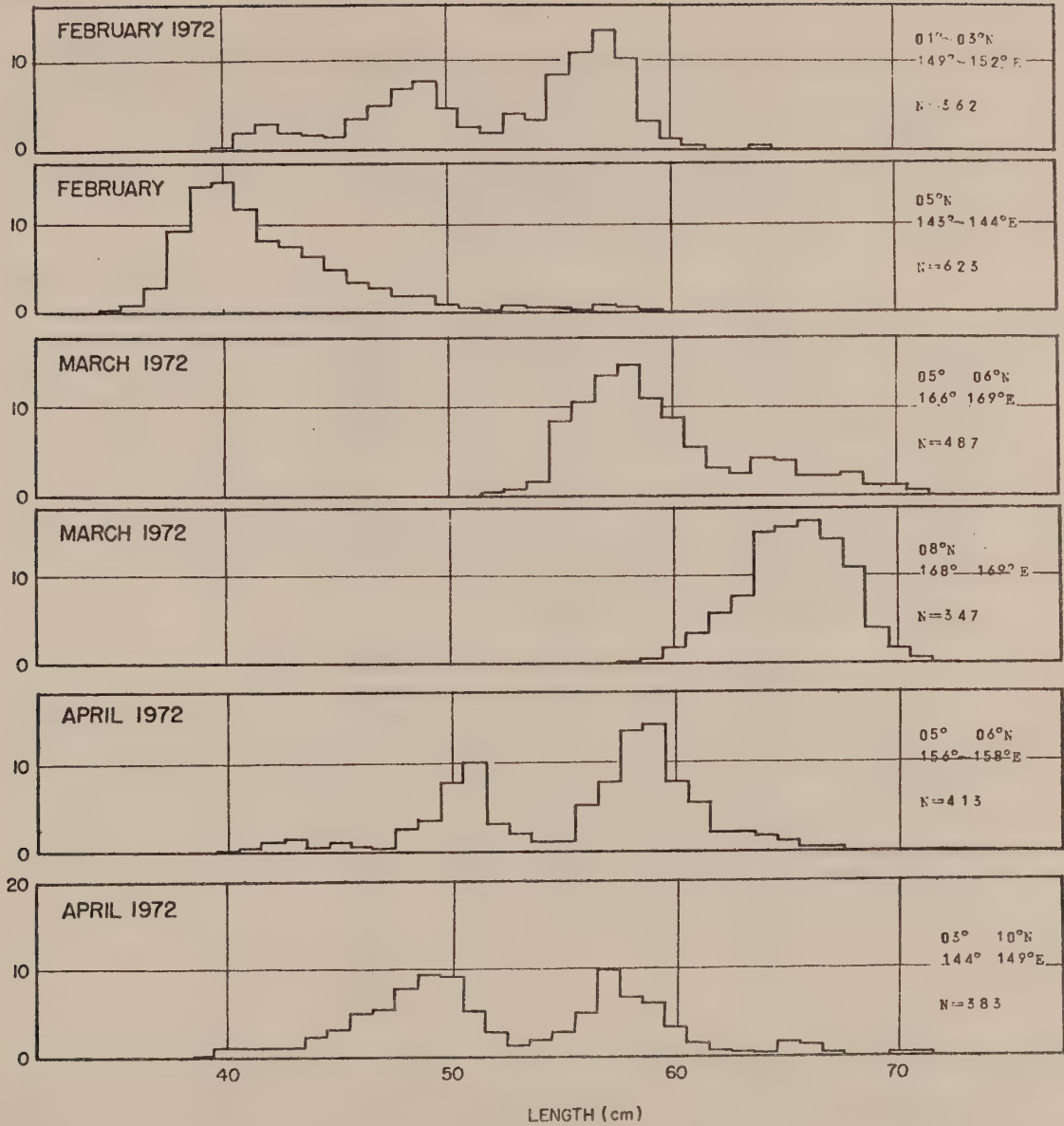


Figure 68.--Continued.

Vessels fishing in Micronesian waters may expect to find skipjack tuna varying in size from about 1 to 27 lb (0.4 to 12.2 kg). In some years, three modal groups can be seen in the length-frequency distribution. In June-December 1964, the 3.4-lb (1.5-kg) group predominated and was considered to be 2-year olds. But by March 1965, they were replaced in the catch by older fish. In 1965, the 6.0-lb (2.7-kg) group predominated in the catch.

The minimum, maximum, and average lengths of skipjack tuna taken in the Palau pole-and-line fishery in 1965-67 are given in Table 40. In general, the vessels caught fish over a wide range of sizes--from 1.2 to 25.4 lb (0.5 to 11.5 kg) but the average size each month fluctuated within a fairly narrow range from 5.6 to 10.4 lb (2.5 to 4.7 kg) (Uchida, 1970). Figure 69 shows that in 1966, two size groups--5.6 lb (2.5 kg) and 11.0 lb (5.0 kg)--predominated in the catch. The bulk of the 1966 catch, however, came from the larger size group. In 1967, three size groups were identified in the length-frequency distribution. These groups had modes at 4.9, 8.7, and 11.6 lb (2.2, 3.9, and 5.3 kg) and all three appeared to be equally represented in the catch.

In the Marshalls, Uchida and Sumida (1973) reported that the skipjack tuna landed by Anela ranged from 3.5 to 23.4 lb (1.6 to 10.6 kg) and averaged 12.3 lb (5.6 kg) whereas yellowfin tuna ranged from 12.3 to 30.0 lb (5.6 to 13.6 kg) and averaged 18.1 lb (8.2 kg) in February. In April-May, however, most of the skipjack tuna taken were medium-sized fish--between 13.0 and 16.5 lb (5.9 and 7.5 kg) and averaging 14.8 lb (6.7 kg). One school of yellowfin tuna fished during this period had fish from 26.9 to 39.7 lb (12.2 to 18.0 kg) and averaging 31.7 lb (14.4 kg).

BY PURSE SEINE

Watakabe (1970) reported on size of skipjack tuna taken by Japanese purse seiners in the western Pacific. In the vicinity of islands and banks, where skipjack tuna "boiler" schools are sometimes seen feeding on bait, the fish are usually large, weighing from 15 to 18 lb (6.8 to 8.2 kg). In waters southeast of Palau at about lat. 4°N, there were numerous reports of schools containing fish varying in size from 7 to 9 lb (3.2 to 4.1 kg) and often mixed with smaller fish of about 4 lb (1.8 kg).

In 1975, Fukuichi Maru, a Japanese seiner, reported that her catch of 187 ST (170 MT) from waters around the Marshall-Caroline Islands consisted of 60% skipjack tuna averaging 7 lb (3.2 kg) and 40% yellowfin tuna varying widely in size from 22 to 66 lb (10.0 to 29.9 kg) (U.S. NMFS, 1974a).

Table 40.--Minimum, maximum, average lengths, and the total number of skipjack tuna sampled in the Palau fishery, by months, May 1965-December 1967 (Uchida, 1970).

Year	Month	Minimum length	Maximum length	Average length	Total number measured
		<u>Cm.</u>	<u>Cm.</u>	<u>Cm.</u>	<u>No.</u>
1965	May	40.7	64.5	50.2	793
	June	31.6	65.4	51.3	3,681
	July	44.6	66.4	53.1	485
	August	31.6	65.6	52.3	1,843
	September	38.8	69.5	52.1	382
	October	45.9	73.4	59.1	786
	November	56.4	74.5	62.1	398
	December	-	-	-	-
1966	January	44.5	65.7	56.4	535
	February	41.1	70.3	54.2	1,054
	March	42.9	70.0	56.2	821
	April	45.3	68.9	53.2	755
	May	42.8	74.0	55.1	1,011
	June	45.0	74.7	56.8	889
	July	38.8	73.5	57.2	2,050
	August	44.2	76.8	57.4	3,337
	September	46.5	68.2	58.1	1,819
	October	47.4	76.3	58.1	2,011
	November	49.7	69.4	60.5	708
	December	49.8	69.9	60.4	346
1967	January	50.0	69.4	61.1	546
	February	38.0	78.3	56.6	334
	March	41.4	68.3	52.9	542
	April	39.8	69.9	53.9	900
	May	40.3	68.2	48.1	1,413
	June	42.0	68.5	51.5	1,256
	July	38.9	69.3	53.6	1,127
	August	44.3	70.0	56.4	1,787
	September	44.4	69.0	56.5	648
	October	43.8	69.1	54.3	777
	November	47.8	72.6	60.9	450
	December	45.8	71.1	58.5	1,278

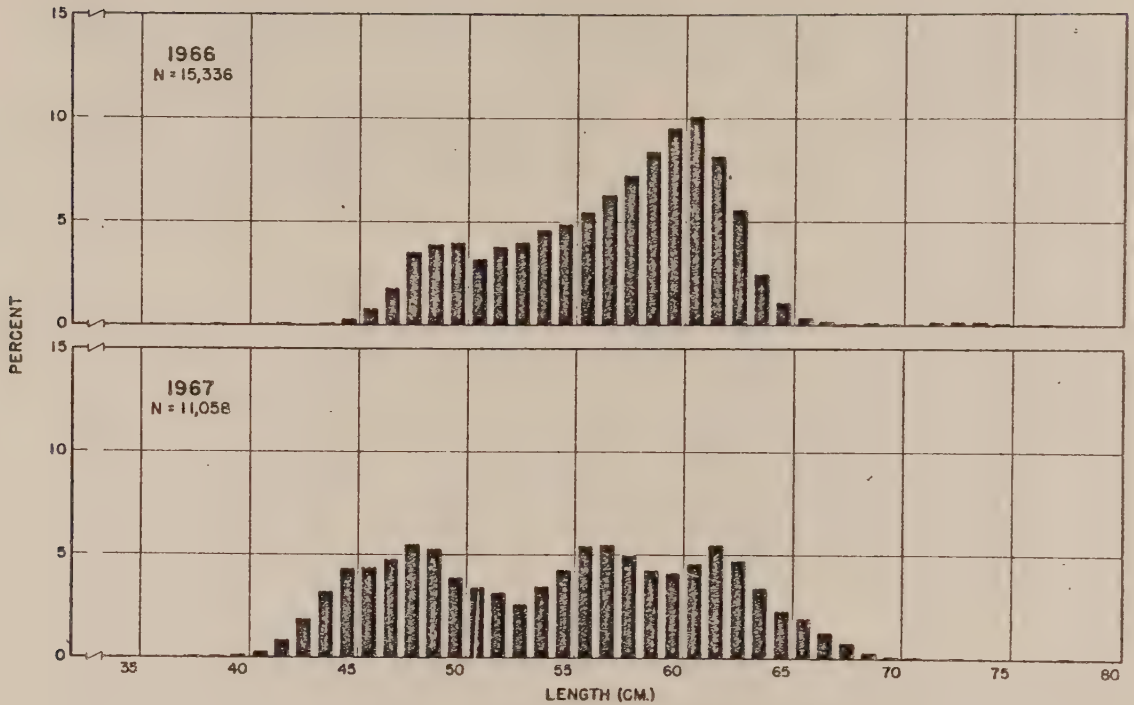


Figure 69.--Length-frequency distributions of skipjack tuna caught by pole-and-line and live bait in Palau waters, 1966 and 1967 (Uchida, 1970).

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Appendix 1

NORTHWESTERN PACIFIC OCEAN

SURFACE CURRENTS AND TEMPERATURES

SOURCE OF INFORMATION

The information relating to monthly surface currents shown on this chart was compiled from observations made during the month for all years prior to 1935 by the co-operating observers of the Hydrographic Office. Observations were not considered reliable where tidal currents prevailed; where winds, sea, or swell of force 6 or above were recorded; where the vessel's draft or trim would cause excessive leeway; or when doubt existed as to the meaning of the entry "Nil" on the current report. All current calculations are based on the MEDIAN POSITION method; namely, each observation is applied at only one point, that point being midway between the beginning and end of the ship's run for which the current observation was made.

RESULTANT CURRENTS

The black arrows and numerals show the mean direction and force of the surface current in each 1-degree quadrangle for the month under average normal conditions. The accuracy of the resultant current in any quadrangle is necessarily determined by the number of observations used in the computation. The Hydrographic Office considers a resultant to be fairly accurate if computed from five or more observations in an area of 3,600 square miles. But on this chart all reliable information is shown, for the benefit of the navigator, even where less than the desired five observations were obtained.

The resultant currents in each 1-degree quadrangle are shown as follows:

The number in the upper right hand corner of the quadrangle represents the total current observations used in the computation. The numerals in the lower left hand corner of the quadrangle give the resultant drift in miles per day to the nearest tenth of a mile. The direction of the arrow in the center of the quadrangle shows the resultant set.

DRIFT SCALE	
KNOTS	
0.00 to 0.33	
0.34 to 0.66	
0.67 to 0.99	
1.00 to 1.33	
1.34 to 1.66	
OVER 1.66	

PREVAILING CURRENTS

The current roses shown in green on this chart were computed from the same information as the 1-degree resultants shown in black. The eight-point rose presents a graphical picture of the frequency of direction and the average drifts within the directions for each area outlined by the heavy brown lines.

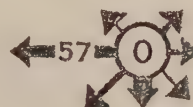
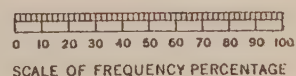
The arrows point in the direction towards which the current sets. When the frequency of direction is less than 5 percent, no arrow is shown. The length of the arrow, from the base of the arrow head to the inner edge of the circle, when placed on the attached frequency scale gives the number of times in each 100 observations that the current has been setting in or near the indicated direction. In instances where the full length of the arrow cannot be shown, the shaft is broken and the true percentage inserted in numerals within the break. The width of the shaft when placed on the attached drift scale gives the average drift in knots. The numeral in the center circle gives the percent of "nils" (no appreciable current observed). The approximate number of observations from which the current rose was computed can be obtained by adding the number of observations within the 1-degree quadrangles covered by the rose.

For example the attached rose should be read as follows:

Of the currents observed; 5 percent were setting northeast, the average drift was between 0.33 and 0.66 of a knot; 5 percent were setting east, the average drift was between 0.33 and 0.66 of a knot; 9 percent were setting southeast, the average drift was less than 0.33 of a knot; 5 percent were setting south, the average drift was between 1.33 and 1.66 knots; 57 percent were setting west, the average drift was between 0.67 and 1 knot; 5 percent were setting northwest, the average drift was less than 0.33 of a knot. The percent of "nils" was zero.

SEA TEMPERATURES

The monthly mean sea surface 5-degree isotherms shown in MAGENTA were compiled from the same source and for the same period as the resultant currents shown on this chart.





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PROCESSING OF A MANUSCRIPT AT SWFC HONOLULU LABORATORY

After discussion with his Investigations Chief, the author prepares an outline of a paper he wishes to write and submits the outline to the Laboratory Director for information. The author here decides which publication he is writing for. If it is an outside journal, he familiarizes himself with the particular journal requirements. If it is an NMFS publication, he may wish to consult the NMFS Style Manual. Copies of this unpublished manual may be borrowed from the library or the Editorial Staff.

The author then prepares a draft, which is critically reviewed by his Investigations Chief and perhaps revised.

This draft is reviewed internally at the author's discretion. He then forwards it to the HL Editorial Staff for editing, checking of literature citations, illustrating, and final typing. At this time any proprietary information it may contain is cleared by the author with the organization supplying the information. This takes place prior to outside review.

After the manuscript is typed in final, copies are sent for outside review (a minimum of two, preferably three). A copy is also sent to the Laboratory Director for review.

After considering the reviewers' comments (and acknowledging with thanks the reviewers' efforts!), the author again submits his manuscript to the Editorial Staff, where it is prepared for submission for SWFC Center Director approval. A Manuscript Transmittal Form is prepared to accompany it. Outside reviewers' names are listed on this form. This form is the author's first (in the case of Marine Fisheries Review his only) opportunity to request reprints in addition to the 50 he will receive (and the 100 the Honolulu Laboratory will receive) gratis.

The Center Director, upon receipt of the manuscript may accept it at this time on the basis that the outside reviews were adequate, or he may have the manuscript reviewed by a reviewer of his choice. The manuscript may be returned to the author for revision. When it is accepted, a copy is forwarded by the Editorial Staff to FI in Washington for information.

It should be noted that all papers, even an outside paper with an HL staff member as junior author, must receive SWFC approval if the work being written about was accomplished while the staff member was employed by the Honolulu Laboratory.

If the manuscript is destined for an NMFS publication: the original and two copies are sent to the NMFS Scientific Editor together with a copy of the Transmittal Form. (The one exception to this is a manuscript destined for Marine Fisheries Review, which is sent directly to the MFR editor.)

The Scientific Editor sends it out to his reviewers, and returns it to the author with reviewers' comments.

After any further revision, the original and one copy are returned to the Scientific Editor. Upon acceptance, he so informs the author.

The manuscript is then forwarded to the Scientific Publications Staff in Seattle. It is then considered "In press."

Page and/or galley proofs are sent to the author by all but Marine Fisheries Review. At this time additional reprints may be ordered (this is your last chance).

If the manuscript is to be published in an outside journal: the original and one or more copies are sent to the publisher with a letter of transmittal. This letter is signed by the Laboratory Editor.

The Editorial Staff also forwards one copy to ESIC (Environmental Science Information Center), Washington, D.C., together with NOAA Form 25-20, as requested.

The manuscript is reviewed by journal reviewers, and in the light of their comments revision may be suggested.

After acceptance and in due time, the author receives page/galley proofs for final corrections. At this time he requests any additional reprints.

Upon publication, the HL Editorial Staff sends to ESIC five copies of reprints together with a completed copy of NOAA Bibliographic Data Sheet (Form 25-13).

Mrs. Toyomura submits a monthly report to SWFC La Jolla detailing the current progress of all HL manuscripts.

* * * * *

June 16, 1975



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
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August 1, 1975

**TO ALL PARTICIPANTS IN THE SEVENTEENTH
HAWAIIAN INTERNATIONAL BILLFISH TOURNAMENT**

The National Marine Fisheries Service is happy to join you in participating in the Seventeenth Hawaiian International Billfish Tournament. As in the past we will be there to perform scientific tasks. I ask your assistance in obtaining the scientific benefits from this outstanding sports fishing event.

We shall continue our shoreside research and ask your permission to make measurements and to cut open your catch for various examinations. Be assured that we will not touch any fish without your permission, nor will we touch it until it has been officially weighed and recorded. If you wish to mount any portion of your prize, all care will be taken not to mar it.

We plan to put up an exhibit at Tournament headquarters. The exhibit is about fish resources and the work of the National Marine Fisheries Service. Frankly, the exhibit is not as complete as we had intended it to be. I hope you find it informative nonetheless.

Heeny Yuen and Ray Sumida will be handling our activities at the Tournament. If you have questions on the biology of billfishes or tunas or the work of the National Marine Fisheries Service, I invite you to try your questions on them wherever you find them.

Attached is our report of last year's Tournament. You may find certain sections in it interesting for your strategy decisions. Other attachments are graphs from which you can estimate a fish's weight by measuring its total length (tip of bill to fork of tail). These graphs, derived from hundreds of measurements, depict the average condition. The fish that you catch will probably vary somewhat from the graph, especially if it is a very large fish.

Thank you very much for your cooperation. Good fishing in the Tournament.

Richard S. Shomura
Director, Honolulu Laboratory

Attachments



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
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TO ALL BILLFISHERS:

The National Marine Fisheries Service, NOAA, has contributed its scientific skills to the Hawaiian International Billfish Tournament (HIBT) and issued reports on its findings for 13 consecutive years. Here again is our traditional report (if you will permit it to be considered traditional after 13 years).

This is the first year that I participated in the HIBT from beginning to end. The spirit of cooperation and community involvement throughout the tournament was truly enjoyable to experience. Bernard Ito, Ray Sumida, Cynthia Unninayar, and I of the National Marine Fisheries Service express our heartfelt thanks to all the anglers, the tournament officials, and the community volunteers for their assistance and the wonderful experience.

The Sixteenth Annual Hawaiian International Billfish Tournament was an unqualified success from the very impressive opening ceremonies through the final awards banquet. It was highlighted by several records. The catch of 110 qualifying fish is the highest ever for any HIBT event. Haku Baldwin's ahi (yellowfin tuna) of 222 pounds on 80-pound test line set a new world's record for women. Neil Nishikawa's feat of landing a Pacific blue marlin of 762 pounds on 50-pound test line also broke a world's record. Congratulations!

THE CATCH

Making up the record catch of 110 fish were 66 Pacific blue marlin, 35 ahi, 6 shortbill spearfish, 2 black marlin, and 1 striped marlin. The first shortbill spearfish appeared in the tournament 3 years ago. The six caught this year are the most ever caught at the HIBT. The black marlin are also noteworthy. Their appearance in the tournament this year terminates an absence of 5 years.

Sixty-four teams of anglers participated in this year's tournament. Their catch of 110 fish calculates out to 2.9 boat-days per fish. If this figure is adjusted for the shortening of the fishing day from 9 hours to 8 hours, the result is 2.5 boat-days per fish. This rate is 20% better than the previous best of 3.1 boat-days per fish (Table 1).

Sex determinations were made on 60 of the Pacific blue marlin. There were 46 males and 14 females, for a male:female ratio of 3.3:1. Sex ratios of Pacific blue marlin in past tournaments (Table 2) have ranged from 1.2 to 8.0:1, with most of them falling between 2:1 and 3:1.

The weight ranged from 127 pounds to 247 pounds for the males and from 86 pounds to 762 pounds for the females. The 86-pound female is a record breaker of dubious distinction. She is the smallest identified female Pacific blue marlin in HIBT records.

AREAS OF STRIKES AND CATCHES

The most popular fishing area was area I, with 425 boat-hours of fishing for the tournament period. Other areas of heavy fishing pressure in order of popularity were: T, J, UA, L, K, V, and UB. Area J provided the most billfishes, with 14 Pacific blue marlin and 1 shortbill spearfish (Table 3). Area T followed with 12 Pacific blue marlin and 1 shortbill spearfish. Area I was third with nine Pacific blue marlin and two black marlin. It is interesting to note that the five leading areas for Pacific blue marlin are areas adjacent to the coast. In fact, 53 of the 66 Pacific blue marlin landed were caught in areas adjacent to the coast.

The largest marlins were caught in areas V and I. The average weight of the Pacific blues caught in areas V and I far exceeded the average weights of the other areas (Table 3). Those caught in area V averaged 419 pounds and those in area I averaged 324 pounds. Compare these averages to the overall average of 224 pounds per Pacific blue marlin. The five blue marlin caught in area V weighed more than all 12 from area T!

Strike rates were calculated for those areas in which there were more than 100 boat-hours of fishing during the tournament (Figure 1). The three top areas were area L with 0.37 strike per boat-hour, area UB with 0.28, and area J with 0.25.

Reasoning that there must be a correlation between strike rates and catch rates because each catch starts as a strike, I plotted the catch rates against the strike rates (Figure 2). The distribution of points on the plot indicates no correlation at all between strike rates and catch rates. In other words, one is just as likely to catch a fish in an area of low strike rate as in an area of high strike rate. This is an enigma to me, but perhaps if I thought like a fish I would see it clearly.

FISHING TACKLE

Tournament fishermen are evidently making better use of the fish caught as far as points are concerned. Since 1970 the use of 130-pound test line has continually decreased (Figure 3) as more and more fishermen are taking advantage of the bonuses offered for catches on light tackle. In 1970, 67% of the fish were caught on 130-pound test; in 1974 only 10%

were caught on 130-pound test. The percentage of fish caught on 80-pound test has increased steadily from 21% in 1970 to 56% in 1974. The rise in percentage of fish caught on 50-pound test from 13% in 1970 to 34% in 1974 was not as consistent as that for 80-pound test. There was a slight decline in 1973, but a sharp increase was witnessed in 1974.

The graph at the top of Figure 3 shows the percentage of hookups that were landed for the last 5 years. In spite of the tendency towards light tackle the proportion of hookups landed has not decreased. Nor has lighter tackle resulted in smaller fish. The frequency distribution of marlin weights for the three different tackles (Figure 4) shows the same pattern for 80-pound test and 50-pound test lines. In view of this I would venture to guess that in a few years 130-pound tackle will not be used at all in the HIBT.

Year after year for 10 years now the strike rates have been superimposed on tide charts as in Figure 5. The relationship between strike rates and tidal phase, if any, remains unclear. In the last 5 years the tournament has been scheduled to coincide with the new moon with dramatic results (Table 1). In 1973 and 1974 whenever a fishing period (equivalent to a radio report period) occurred during low tide, that period had the highest strike rate for the day. In Table 4a I have summarized the tide phase rankings based on strike rates for the last 5 years (1970-1974 inclusive). The strike rates at low water slack tide ranked first in 3 years and second in 2 years. The strike rates during flood tide periods ranked first 1 year and last in 4 years. High water slack tide ranked second in 1 year and last in another. Ebb tide ranked first in 1 year and second in 2 years. From Table 4a low water slack tide appears to be the best time for strikes and flood tide the worst. From 1965 to 1969, when tournaments were not scheduled according to moon phase, a similar summary (Table 4b) shows that strike rates were best during ebb tide. Data in the next few years should result in a decision on whether or not strike rates are related to tide phases.

STOMACH CONTENTS

Fishes of the tuna family were the most common food item found in marlin stomachs this year. They occurred in 45% of the stomachs examined. This occurrence rate of tunas is higher than any recorded for the HIBT in the past. The two dominant species of tunas were skipjack tuna in 20% of the stomachs and frigate mackerel in 18% of the stomachs. The next most common on the list of food items (Table 5) was squid, which was found in 22% of the stomachs. Opelu, a mackerel scad, was also a popular item with an occurrence of 18%. Over the years tunas, squid, and opelu have been the mainstay of the diet of marlins during the tournament. Twenty-two percent of the stomachs were empty.

The stomach contents included a juvenile scorpionfish and a blade of seaweed, items never seen in marlin stomachs in past tournaments. On the other hand, goatfish juveniles were notably missing. The earliness of this year's tournament may have been a factor in their absence as these juveniles usually enter the coastal waters during August and September.

I enjoyed meeting you. Until next year, aloha and good fishing.

Heeny S. H. Yuen
Heeny S. H. Yuen
Fishery Biologist

September 12, 1974

Attachments

Table 1.--Numbers of qualifying game fish landed and teams fishing during Hawaiian International Billfish Tournaments, 1962-74.

Year	Blue marlin	Black marlin	Striped marlin	Shortbill spearfish	Sailfish	Yellowfin tuna > 100 lb.	Total qualifying fish	Number of teams	Number of boat-days fishing per fish
1962	30	1	--	--	1	19	51	68	6.7
1963	19	2	1	--	--	26	48	72	7.5
1964	31	--	1	--	--	2	34	69	10.1
1965	47	--	--	--	--	9	56	78	6.9
1966	26	3	2	--	--	7	38	72	9.5
1967	63	--	1	--	--	18	82	68	4.2
1968	36	2	4	--	--	4	46	85	9.2
1969	32	1	--	--	--	4	37	75	10.1
1970	91	--	2	--	2	14	109	73	3.3
1971	41	--	3	1	--	47	92	77	3.4
1972	77	--	--	--	--	11	88	59	3.4
1973	76	--	1	3	1	17	98	61	3.1
1974	66	2	1	6	--	37	110	64	2.5

Table 2.--Sex ratios for blue marlin, Makaira nigricans, examined from Hawaiian International Billfish Tournaments, 1962-74.

Year	Number of males	Number of females	Ratio males to females
1962	16	7	2.3:1
1963	13	6	2.2:1
1964	14	12	1.2:1
1965	35	8	4.4:1
1966	16	8	2.0:1
1967	51	13	3.9:1
1968	24	10	2.4:1
1969	23	8	2.9:1
1970	63	14	4.5:1
1971	21	9	2.3:1
1972	64	8	8.0:1
1973	47	21	2.2:1
1974	46	14	3.3:1

Table 3.--Number of fish caught in 1974 tournament by species, date, and area.

Date	Area												
	C	I	J	K	L	M	N _A	N _B	S	T	U _A	U _B	V
Pacific blue marlin													
July 15	--	--	2	1	3	--	--	--	1	1	1	2	--
July 16	1	1	2	--	--	--	--	--	1	2	1	2	--
July 17	--	3	6	1	--	--	--	--	--	1	--	--	--
July 18	1	4	3	1	--	--	--	--	2	4	1	--	4
July 19	--	1	1	1	1	1	1	1	2	4	--	--	1
Total	2	9	14	4	4	1	1	1	6	12	3	4	5
Average weight	123.0	323.9	189.6	213.8	195.8	136.0	162.0	182.0	229.3	162.9	170.0	221.8	419.2
Ahi													
July 15	--	1	1	--	--	--	--	--	--	1	--	--	--
July 16	--	3	1	2	--	--	--	--	--	--	--	--	--
July 17	--	3	2	--	--	3	1	--	2	--	1	1	--
July 18	--	2	--	--	1	--	--	--	1	--	2	1	1
July 19	--	--	1	--	--	--	--	1	--	--	--	--	--
Total	--	9	5	2	1	3	1	1	3	1	3	2	1
Average weight	--	159.2	183.2	155.0	111.0	217.3	217.0	120.0	136.7	170.3	200.7	189.0	199.0
Other*													
July 15	--	BM	--	--	SS	SS	--	--	--	--	--	--	--
July 16	--	--	--	--	--	--	--	--	--	--	--	--	--
July 17	--	--	--	--	--	--	--	--	--	--	--	SS	SM
July 18	--	BM	--	--	SS	--	--	--	--	SS	--	--	--
July 19	--	--	SS	--	--	--	--	--	--	--	--	--	--
Total	--	2	1	--	2	1	--	--	--	1	--	1	1
Average weight	--	342.5	26.0	--	23.5	29.0	--	--	--	34.0	--	42.0	35.0

*One fish caught in each cell marked by symbol; BM = black marlin, SM = striped marlin, SS = shortbill spearfish.

Table 4.--Number of years strike rates of tide phases fell in various ranks.

a. 1970-74 inclusive

Tide phase	Strike rate rank		
	1	2	3
Low-water slack	3	2	-
Flood	1	-	4
High-water slack	-	1	1
Ebb	1	2	-

b. 1965-69 inclusive

Tide phase	Strike rate rank			
	1	2	3	4
Low-water slack	-	2.5*	2.5*	-
Flood	-	2.5*	1.5*	1
High-water slack	2	-	1	-
Ebb	3	-	-	1

*Tie in rankings 1 year.

Table 5.--Stomach contents of Pacific blue marlin, Makaira nigricans, from the Hawaiian International Billfish Tournament, 1974

Food items	Date and number of stomachs containing listed food items					Percent occurrence
Fish	7/15	7/16	7/17	7/18	7/19	
Tuna, Scombridae						45
Skipjack tuna, <u>Katsuwonus pelamis</u>	2	1	3	3	1	20
Frigate mackerel, <u>Auxis</u> sp.	1	1	2	4	2	18
Unidentified	1	-	2	2	-	10
Jacks, Carangidae						20
Opelu, <u>Decapterus pinnulatus</u>	1	1	1	4	2	18
Akule, <u>Trachuroops crumenophthalmus</u>	-	1	-	-	-	2
Mahimahi, Coryphaenidae	-	-	1	1	1	6
Pelagic spiny puffer, Diodontidae	2	2	-	1	1	12
Puffer, Tetraodontidae	-	-	-	1	-	2
Triggerfish, Balistidae	-	-	-	-	2	4
Surgeonfish, Acanthuridae	-	-	1	1	-	4
Lancetfish, Alepisauridae	-	1	1	2	1	10
Snake mackerel, Gempylidae	-	3	-	-	1	8
Butterflyfish, Chaetodontidae	-	-	2	-	-	4
Scorpionfish, Scorpaenidae	-	-	-	1	-	2
Cowfish, Ostraciontidae	-	-	-	1	-	2
Unidentified fish	3	3	4	7	4	43
Invertebrates						
Squid, Decapoda	3	3	1	-	4	22
Empty or everted stomachs	1	3	1	5	1	22
Number of stomachs examined	8	8	11	15	7	
Total: 49						

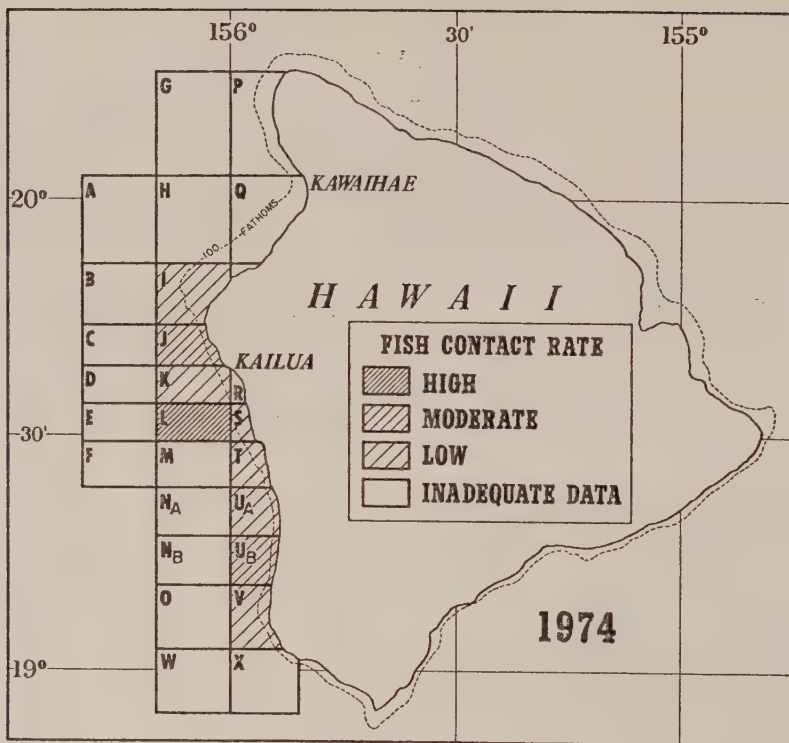


Figure 1.--Fish contact rates in the various fishing areas.

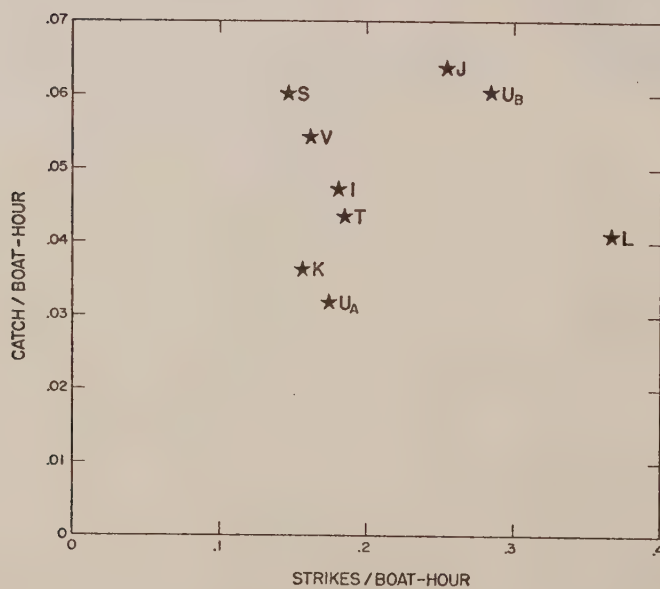


Figure 2.--Plot of catch rates against strike rates. Letters refer to areas.

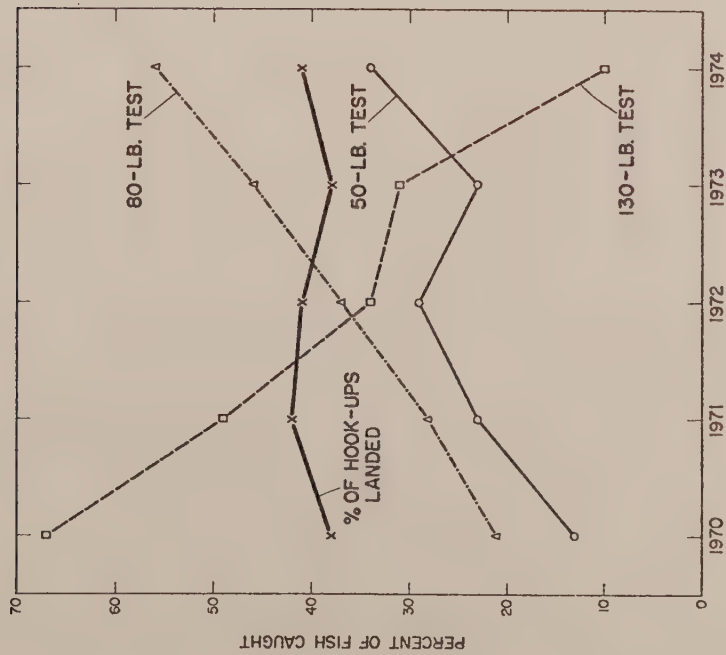


Figure 3.--Proportion of catch landed on various size lines.

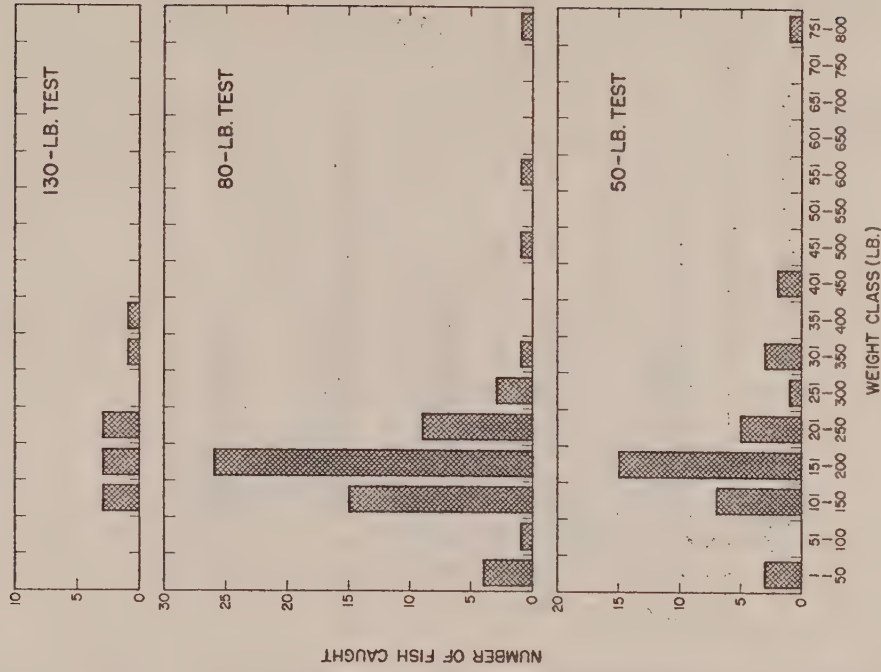


Figure 4.--Frequency distribution of weights of fish caught on various size lines.

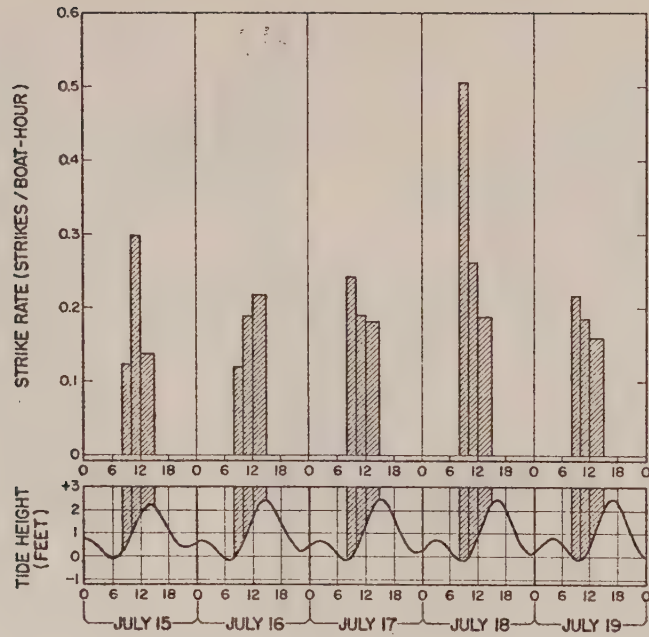
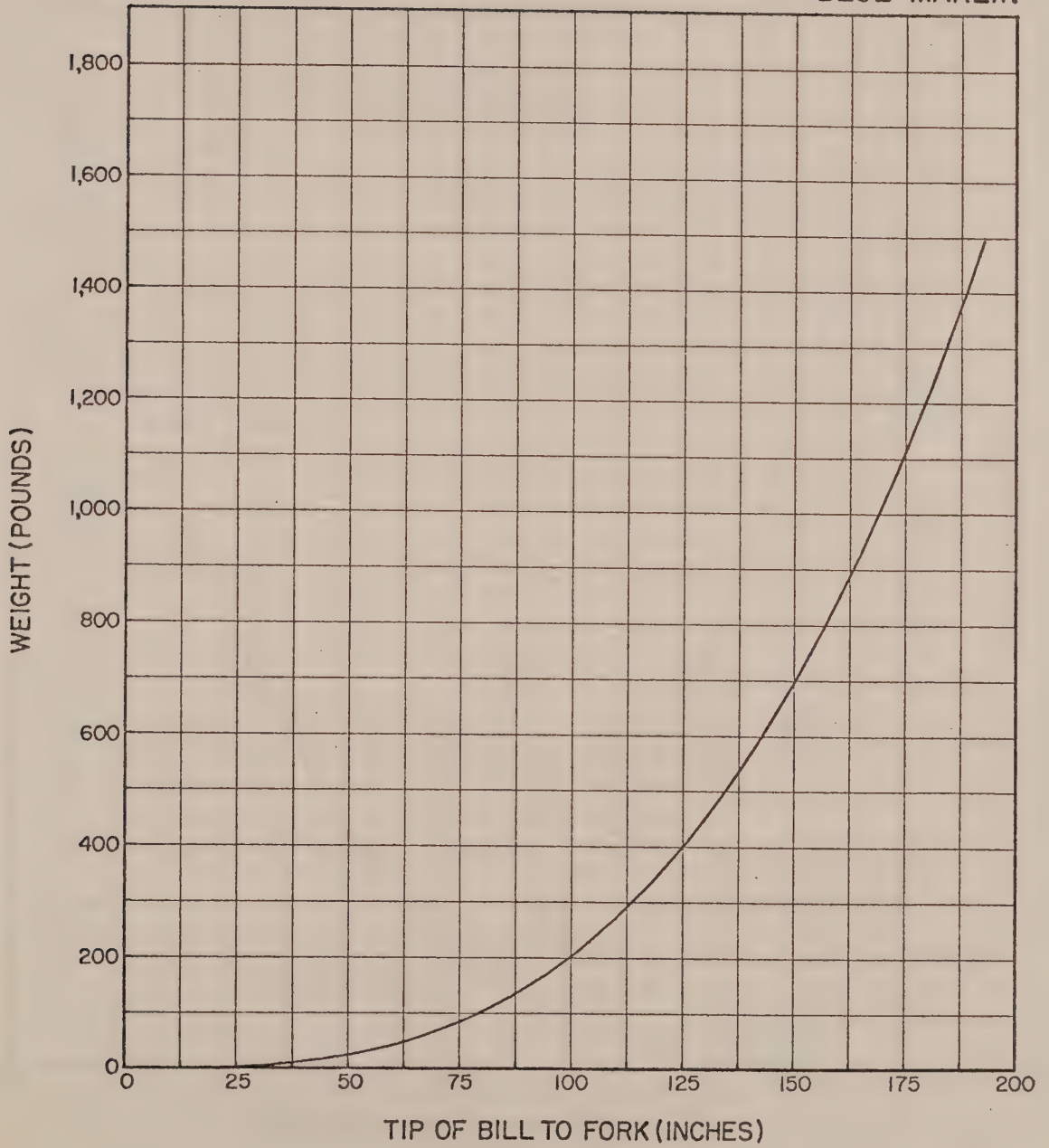
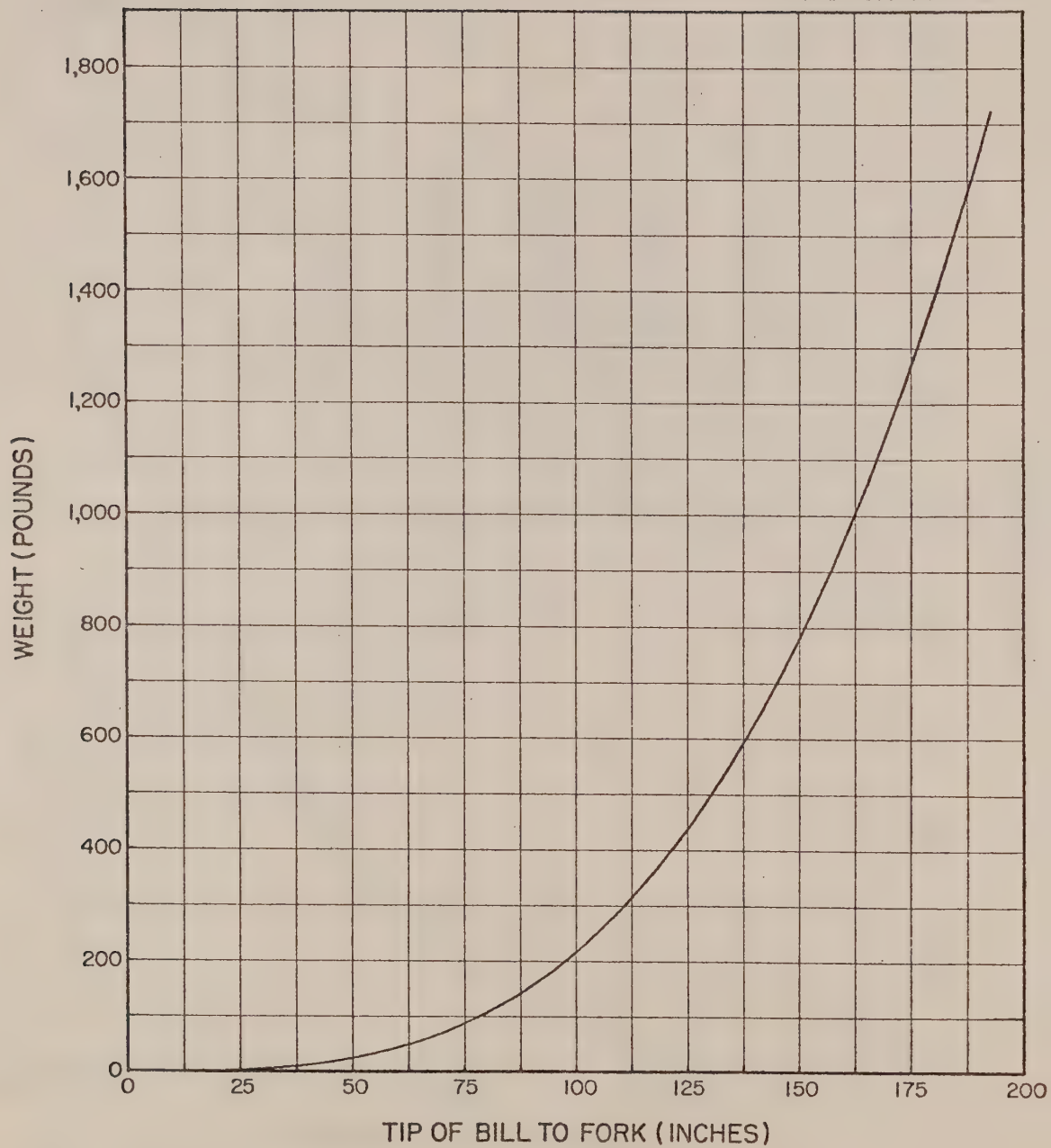


Figure 5.--Strike rates and tide cycle for 1974 HIBT.

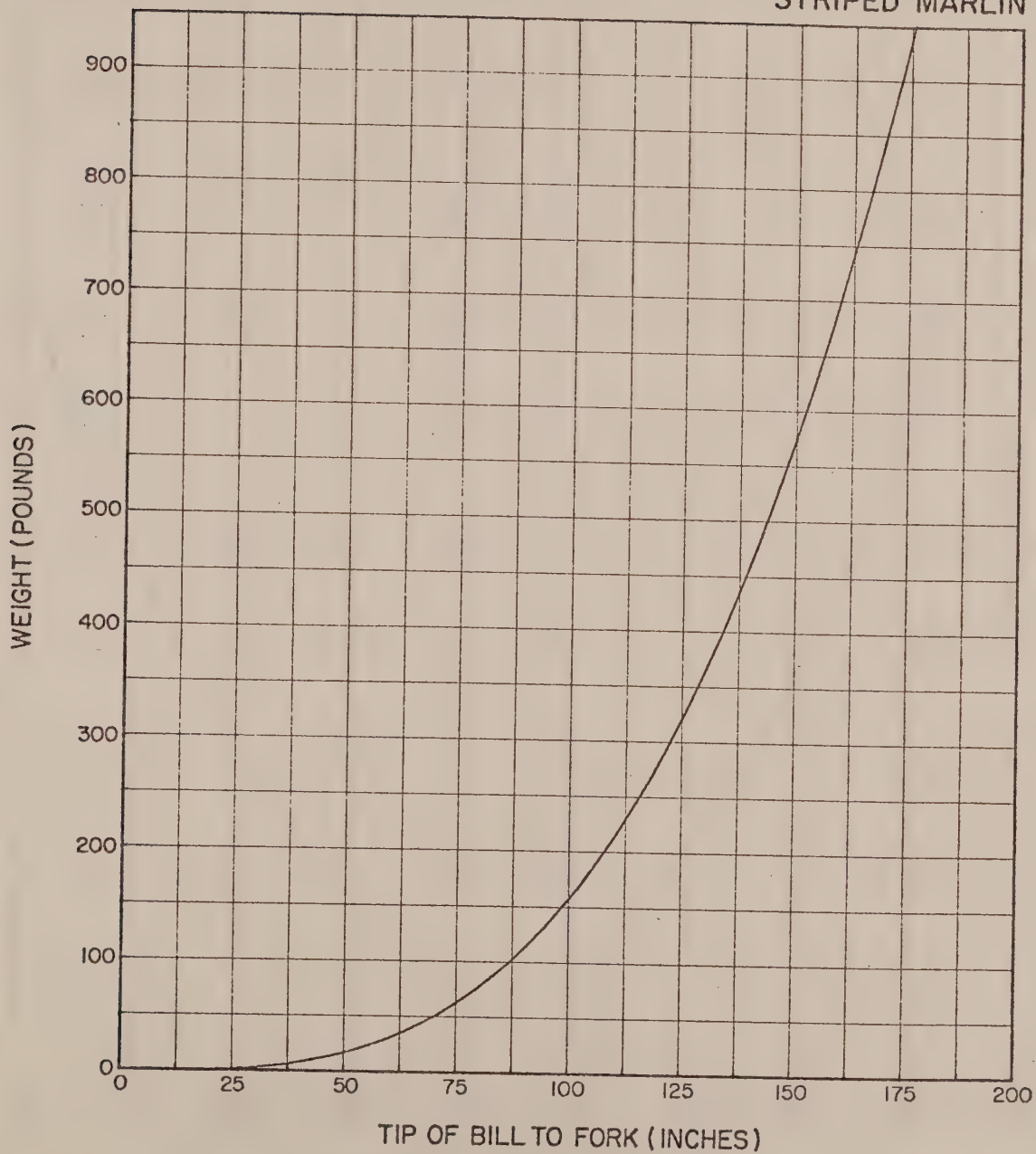
BLUE MARLIN



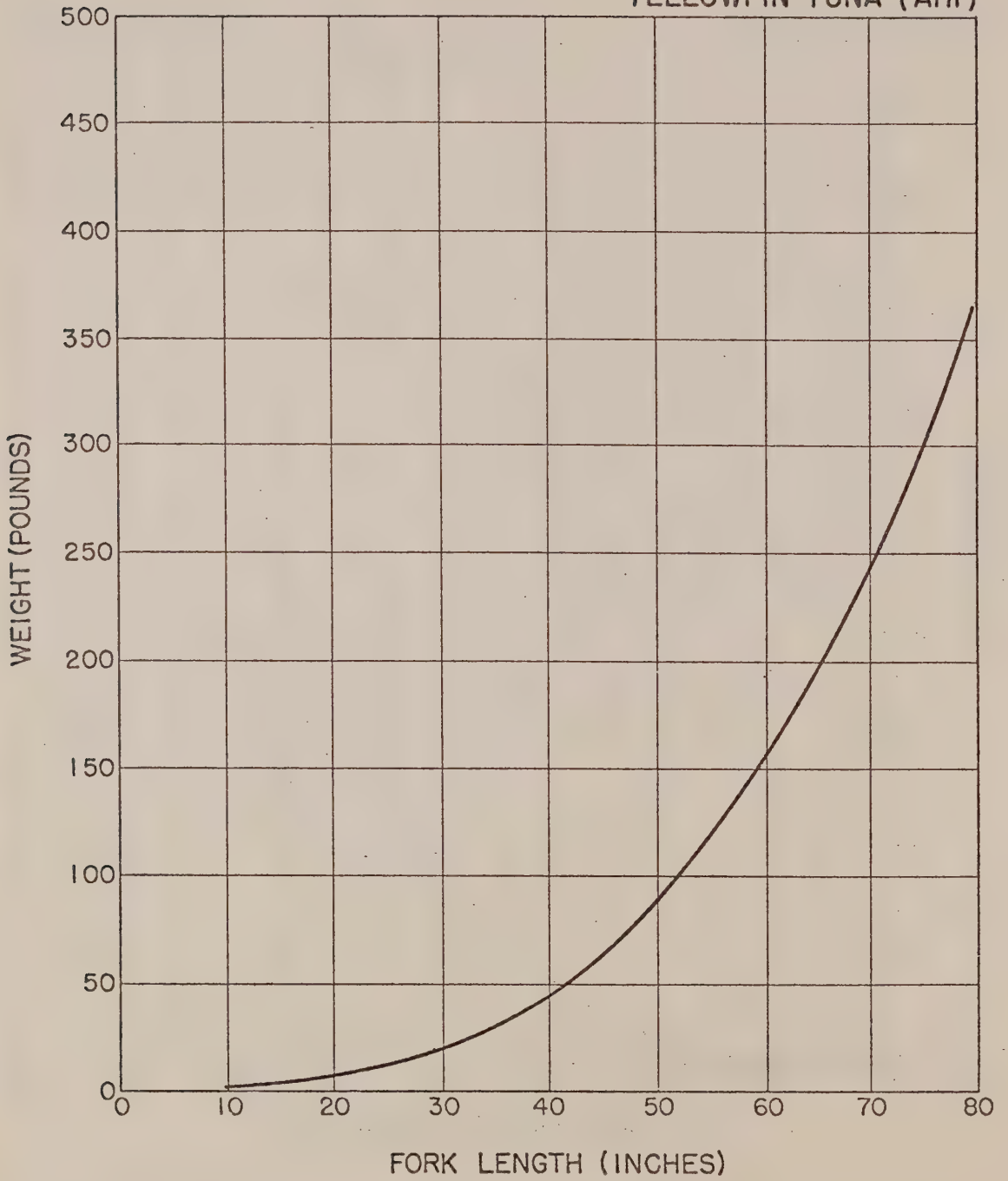
BLACK MARLIN



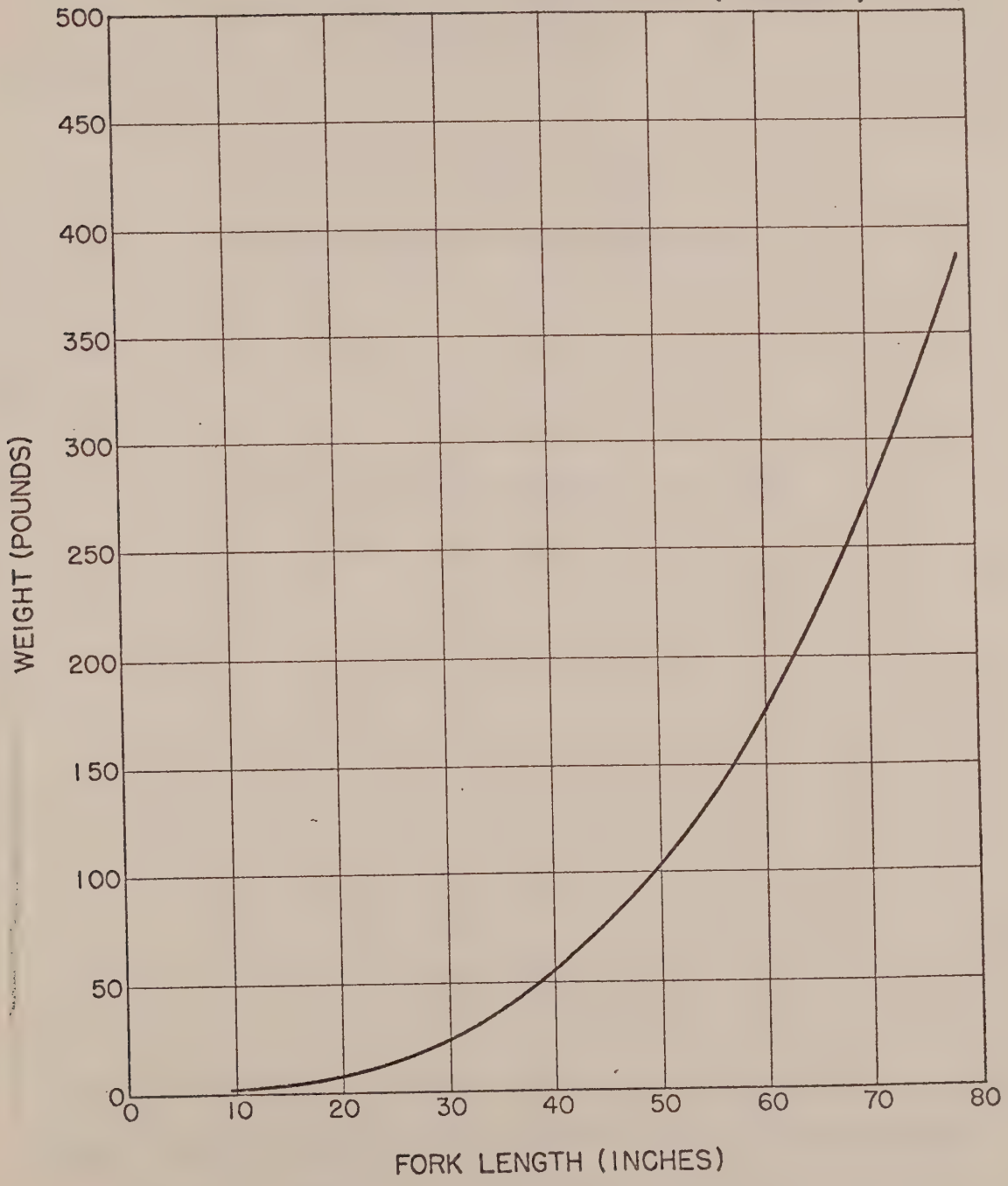
STRIPED MARLIN



YELLOWFIN TUNA (AHI)



BIGEYE TUNA (MEBACHI, SHIBI)



DRAFT FOR COMMENT

THE BIOLOGY, ECOLOGY, AND RESOURCE
OF THE SKIPJACK TUNA, KATSUWONUS PELAMIS

Walter M. Matsumoto and Robert A. Skillman¹

October 1975

¹Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

This is a draft report distributed for comment only. It will not be published in the present form and should not be cited in the literature.

SYNOPSIS OF BIOLOGICAL DATA ON FRIGATE MACKERELS,

GENUS AUXIS

Richard N. Uchida¹

¹Southwest Fisheries Center, National Marine Fisheries Service,
NOAA, Honolulu, HI 96812.

INTRODUCTION

Unlike a number of tuna species in the world's oceans which are heavily exploited and possibly are being harvested near the upper limit of rational utilization, frigate mackerels, the most primitive member among the higher tunas (Thunnini), give every indication of being an underutilized fishery resource. In planning for the rational utilization of this resource, it is imperative to have on hand information concerning the biology of the species and estimates of present and potential catches. The purposes of this report, therefore, are to update our current knowledge of the species by bringing together and extracting all the available information on the biology and fisheries for frigate mackerels and to review and evaluate in depth the results of past research, indicating in particular where conflicting evidence exists.

THE BIOLOGY AND RESOURCES OF THE SPECIES OF EUTHYNNUS

Howard O. Yoshida¹

October 1975

¹Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

This is a draft report distributed for comment only. It will not be published in the present form and should not be cited in the literature.

THE BIOLOGY AND RESOURCES OF THE BONITOS,

GENUS SARDA

Howard O. Yoshida¹

October 1975

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DRAFT

A COHORT ANALYSIS OF THE NORTH PACIFIC ALBACORE STOCK
AND AN ASSESSMENT OF YIELD PER RECRUIT
IN THE AMERICAN AND JAPANESE FISHERIES

Jerry A. Wetherall and Marian Y. Y. Yong¹

November 1975

¹Southwest Fisheries Center, National Marine Fisheries Service,
NOAA, Honolulu, HI 96812.

This is a draft working paper prepared solely for discussions at the Workshop on Population Dynamics of North Pacific Albacore. It is not intended for publication in its present form and should not be cited.



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu and La Jolla Laboratories
P. O. Box 3830
Honolulu, Hawaii 96812

TO ALL BILLFISHERS:

Here is the report from the National Marine Fisheries Service on the Seventeenth Hawaiian International Billfish Tournament (HIBT). Veteran anglers of the HIBT are familiar with this report. I'll give a short background for the rookies. For the last 14 years the National Marine Fisheries Service has sent representatives to HIBT. The representatives make observations and collect data. They also put up exhibits, give talks, give demonstrations and in so doing, provide a little spice to the tournament. After the tournament, the data and observations are examined, analyzed, and studied. The resulting information is summarized in a report to you. This is it.

Many people made it possible for us to get our job done. To the anglers, tournament officials, and volunteers from the community, Ray F. Sumida and I of the National Marine Fisheries Service extend our thanks for your wholehearted cooperation and support. Working with people who are enthusiastic and totally involved is exciting. We acknowledge you for a great and satisfying experience.

The Seventeenth Hawaiian International Billfish Tournament was a tournament of mosts. In the history of HIBT this tournament had: (1) the most blue marlin caught, (2) the most ahi (yellowfin tuna) caught, (3) the most shortbill spearfish caught, (4) the most qualifying fish caught, (5) the most world records surpassed by individual anglers, and (6) the most impressive and delicious pupus served at a cocktail party.

THE CATCH

Tournament competitors caught 193 fish. This phenomenal number becomes even more so in light of the previous high of 110 fish caught in 1974 (Table 1). The number of fish caught in this tournament is 75% more than the highest number caught in earlier tournaments and 182% more than the average tournament catch.

Another way to look at the catch is to relate it to the fishing effort. This year 79 teams participated. The number of boat-days of fishing per fish was 2.0. In the extreme right column of Table 1 is listed the statistics for previous years. This year's 2.0 boat-days per fish is better by 31% than the previous best of 2.9 boat-days per fish.

The catch consisted of 104 blue marlin, 79 ahi, 8 shortbill spearfish, and 2 striped marlin. The weight range of the blue marlin was 107-536 lb with an average of 207 lb. Half of the blue marlin weighed less than 185 lb. The ahi ranged from 102 to 261 lb and averaged 186 lb. The smallest and largest shortbill spearfish weighed 25 and 39 lb, respectively. The striped marlin were 53 and 56 lb.

Sex determinations were made on 86 of the blue marlin. The male to female ratio was 4.4:1. The ratio of males to females has ranged from 1.2:1 to 8:1 over the past 14 years (Table 2). Occasionally someone will point out that there is an apparent correlation between a high occurrence of males and a high catch. This correlation was investigated. Because of a sharp increase in catch rates since 1970 (to be discussed later), the data prior to that year could not be treated together with the later data (Figure 1). Statistical procedures on the data showed no significant correlation between catch rate and the ratio of males to females. It is possible that with more data points the correlation will show significance. Additional data points will be collected at future tournaments.

FISHING AREAS

Your daily radio reports were analyzed for information. Area India was the most popular by far. The reports show that 945 boat-hours of fishing were spent in area India. Area Juliet was second with 388 boat-hours of fishing. Other favored areas ranked in order were: Sierra, Lima, Uniform B, Kilo, Uniform A, and Tango. The following analyses of areas are restricted to the aforementioned areas, in which 100 or more boat-hours of fishing time were spent.

There was no area with a high strike rate. Area Uniform B had the highest with 0.28 strike per boat-hour. Compared to 1974, the strike rates were more evenly distributed (Figure 2). In 1974 the strike rates were high in one area, moderate in two areas and low in six areas. This year the strike rates were moderate in six areas and low in two areas. Area India had a lot of strikes (197) but also had a high number of boat-hours. The result was a moderate strike rate. With respect to strike rates, area India ranked fifth among the eight areas analyzed.

The distribution of the catch by area and date is presented in Table 3. Area India provided the highest catch with 69 fish. Area Juliet with a yield of 36 fish was a far second. As with the strike rate, the catch per boat-hour in area India was low because of the many boat-hours expended in that area. Of the eight areas considered, area India ranked sixth in catch rate. Generally, the correspondence between strike rate and catch rate was good (Figure 3) with the exception of area Uniform B which had the highest strike rate and ranked seventh in catch rate.

ANALYSIS OF FISHING

The extraordinary increase of this year's catch over last year's catch warranted an investigation into the causes of the increase. Undoubtedly one can approach this by various methods. I chose to consider the amount of fish caught as being the product of three factors: strike rate, boat-hours of fishing, and percent of strikes landed. Strike rate is an index of the availability of fish in the tournament areas, a factor which is uncontrolled by man so far. Boat-hours of fishing is a measure of the fishing effort. That is almost entirely controlled by the Governors of HIBT. I say almost entirely because although they decide on the number of teams fishing, they don't control the breakdowns or the fighting time, which are taken into consideration in the calculation of boat-hours of fishing. Percent of strikes landed is a measure of your skill as anglers and the teamwork between anglers and boat captains.

The results of the analysis were a surprise. The availability of fish between the 2 years was not very different...0.22 strike per boat-hour for 1975 and 0.21 for 1974. The increase in fishing effort was obvious. There were 79 competing teams in 1975 and 64 in 1974. The major factor contributing to the increase was the percent of strikes landed: 33.6% in 1975 compared to 23.6% in 1974. The apportionment of the increase in catch of 1975 over 1974 to the various causes is as follows:

Availability of fish	8%
Fishing effort	29%
Skill of anglers	63%

The statistics show that you, the anglers, were mostly responsible for the great catch in HIBT 1975. Congratulate yourselves.

FISHING TACKLE

The trend towards using lighter line continued in this tournament. The percent of fish caught on 130-lb test line dropped to 3.1%, on 80-lb test line dropped slightly to 52.1%, and on 50-lb test line rose to 44.8% (Figure 5). The decline in the use of 80-lb test line ended a steady increase in its use since 1970. Most of the fish were still caught on 80-lb test line, however. When the catch on various lines is analyzed by species (Figure 4), we see that more blue marlin were caught on 50-lb test than on any other line whereas most of the ahi were caught on 80-lb test.

The weight distributions of the fish caught on lines of various strengths (Figure 5) are similar. The average weights of blue marlin caught on 50- and 80-lb tests were 198.2 lb and 216.1 lb, respectively. For ahi the averages were 183.0 lb and 188.9 lb. Statistical tests show no significant difference between the weights of fish caught on 50- and 80-lb tests.

A question that naturally arises with the greater use of 50-lb test line is, "Are more fish getting away?" There are no data on the percentage of hookups landed for the various line strengths used. The overall percentage of hookups landed this year was 46% (Figure 4). This is the highest percentage of hookups landed since 1970. The use of 50-lb test line was also greatest. Apparently the use of 50-lb test line in preference over heavier lines does not increase the loss of fish during fishing. On the other hand, the weight distribution graph (Figure 5) shows that six blue marlin over 300 lb were caught on 80-lb test line compared to three on 50-lb test line. Perhaps the big ones are getting away. The numbers are small, however, and may be the result of chance.

Analyses of data on fighting time produced more results that were surprising. Fighting time for blue marlin caught on 50-lb test line did not differ significantly from that of 80-lb test. The average fighting time was 41.6 minutes on 50-lb test and 42.1 minutes on 80-lb test. Fighting time of blue marlin on 50-lb test was not related to the weight of the fish. On 80-lb test the relationship between fighting time and weight of fish was statistically significant although points on a graph of fighting time on weight (Figure 6) were quite scattered. The fighting time data for the ahi presented a completely different picture from the blue marlin data, a picture that conformed much more to my expectations. The average fighting time of 92.2 minutes for ahi on 50-lb test was significantly different from the average of 46.1 minutes for ahi on 80-lb test. Fighting time was related to the weight of the fish on both lines (Figure 7). The weight of the fish had a greater effect on fighting time with 50-lb test than it did with 80-lb test. Lines defining the relationship between fighting time and fish weight for both lines are shown in Figure 7. The slope of the line for 50-lb test is three times the slope for 80-lb test.

STOMACH CONTENTS

The stomachs of 76 blue marlin were cut open and their contents examined.

We identified 12 different species of fish in the stomachs. Some of the fish were digested beyond recognition and others could be identified as belonging to the tuna family but no further. In addition to fish, the stomachs also contained squid. The items, the number of stomachs they occurred in, and the percent of the stomachs they occurred in, are listed in Table 4. The most common item was skipjack tuna, which occurred in 43% of the stomachs. Seventy percent of the stomachs contained some species of tuna. Squid occurred in 25% of the stomachs; opelu, a mackerel scad, in 17%; and pelagic spiny puffer in 12%.

Fish found in the stomachs were measured. Much of the fish remains were not measurable but we were able to count the number of fish which contributed to the remains. Lengths of the fish found in the stomach (Figure 8) ranged from 1/2 to 24 inches. Slightly over half of the fish (57%) were longer than 6 inches. The largest fish was a mahimahi. Species that made up the larger fishes in the stomach were: skipjack tuna, pelagic puffer, opelu, and mahimahi.

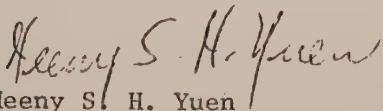
TIDES AND TIME

Since 1970 HIBT has been scheduled to coincide with the new moon. The two- to threefold increase in catch that resulted is now an old story. Every year the tournament report has included a graph of the rate of strikes superimposed on the tide pattern (Figure 9). Inspection of these graphs has shown no consistent relationship between strike rate and tide phase. The HIBT strike rates for various phases of the tide for the years 1970-75 inclusive were averaged (Figure 10). The average strike rate was highest during the low water slack tide. Statistical tests showed a significant difference between the strike rates of low water slack tide and rising tide. The strike rates of other tidal phases did not differ significantly.

This year's catches of blue marlin and ahi were plotted against the hour at which the fish struck (Figure 11). The graph for the blue marlin shows a peak for the hour 11-12 o'clock. That peak was primarily the result of 10 blue marlin caught at that hour during the last day of the tournament. During the other 4 days of fishing the catch during that hour did not vary very much from the hourly average for the day. The graph for ahi shows peaks for the hour 9-10 and 11-12. These peaks were the result of consistent catches for those hours throughout the week. A feature of both the marlin and ahi graphs is the low catch during the first hour of the day. The low catch is to be expected because the teams travel to the fishing grounds during that hour.

To the many, many workers up front and behind the scenes, to the participating anglers, and to the charter boat captains and crews: Congratulations for creating an excellent tournament.

Until we meet again at the next annual Hawaiian International Billfish Tournament, Aloha.



Heeny S. H. Yuen
Leader, Recreational Fisheries

Attachments

November 20, 1975

Table 1.--Numbers of qualifying game fish landed and teams fishing during
Hawaiian International Billfish Tournaments, 1962-75.

Year	Blue marlin	Black marlin	Striped marlin	Shortbill spearfish	Sailfish	Yellowfin tuna ≥ 100 lb	Total qualifying fish	Number of teams	Number of boat-days of fishing, per fish
1962	30	1	--	--	1	19	51	68	6.7
1963	19	2	1	--	--	26	48	72	7.5
1964	31	--	1	--	--	2	34	69	10.1
1965	47	--	--	--	--	9	56	78	6.9
1966	26	3	2	--	--	7	38	72	9.5
1967	63	--	1	--	--	18	82	68	4.2
1968	36	2	4	--	--	4	46	85	9.2
1969	32	1	--	--	--	4	37	75	10.1
1970	91	--	2	--	2	14	109	73	3.3
1971	41	--	3	1	--	47	92	77	3.4
1972	77	--	--	--	--	11	88	59	3.4
1973	76	--	1	3	1	17	98	61	3.1
1974	66	2	1	6	--	37	110	64	2.9
1975	104	--	2	8	--	79	193	79	2.0

¹Nine-hour fishing days, 1962-73; 8-hour days in 1974 and 1975.

Table 2.--Sex ratios for blue marlin examined
from Hawaiian International Billfish Tournaments, 1962-75.

Year	Number of males	Number of females	Ratio males to females
1962	16	7	2.3:1
1963	13	6	2.2:1
1964	14	12	1.2:1
1965	35	8	4.4:1
1966	16	8	2.0:1
1967	51	13	3.9:1
1968	24	10	2.4:1
1969	23	8	2.9:1
1970	63	14	4.5:1
1971	21	9	2.3:1
1972	64	8	8.0:1
1973	47	21	2.2:1
1974	46	14	3.3:1
1975	70	16	4.4:1

Table 3.--Number of fish by species, area, and date from Hawaiian International Billfish Tournament 1975.

	A	C	D	H	I	J.	K	L	M	N _A	N _B	R	S	T	U _A	U _B	V
Blue marlin																	
August 4	--	--	1	--	8	6	2	--	--	--	--	1	4	1	1	--	1
August 5	--	2	--	--	9	2	1	1	--	--	--	--	2	1	2	--	1
August 6	--	--	--	--	10	1	1	4	--	--	--	--	1	3	--	2	1
August 7	--	--	--	--	2	1	--	1	--	--	--	--	1	1	--	2	--
August 8	1	--	--	--	8	3	3	2	1	1	1	--	--	1	2	3	1
Total	1	2	1	--	37	13	7	8	1	1	1	1	8	7	5	7	4
Average weight (lb)	153.0	178.0	207.0	--	212.6	225.0	252.6	169.4	149.0	364.0	246.0	263.0	218.8	195.6	172.8	157.6	203.3
Ahi																	
August 4	--	--	--	--	4	6	1	2	--	1	--	--	--	1	2	--	--
August 5	--	--	--	2	8	4	--	--	--	--	--	--	1	1	1	--	--
August 6	--	--	--	--	9	1	1	--	--	--	--	--	--	--	--	1	--
August 7	--	--	--	--	7	6	2	--	--	--	--	--	--	2	--	--	--
August 8	--	--	--	--	3	2	1	1	1	--	2	--	1	2	1	2	--
Total	--	--	--	2	31	19	5	3	1	1	2	--	2	6	4	3	--
Average weight (lb)	--	--	--	256.5	184.5	186.4	203.6	171.3	178.0	132.0	176.0	--	132.5	191.5	175.3	206.7	--
Striped marlin																	
August 4	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--
Average weight (lb)	--	--	--	--	--	54.5	--	--	--	--	--	--	--	--	--	--	--
Shortbill spearfish																	
August 4	--	--	--	--	--	1	--	--	--	2	--	--	--	--	--	--	--
August 5	--	--	--	--	1	--	--	--	--	--	--	--	1	--	--	--	--
August 7	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	--	--
August 8	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Total	--	--	--	--	1	2	1	--	--	2	--	--	1	--	1	--	--
Average weight (lb)	--	--	--	--	32.0	31.5	37.0	--	--	35.5	--	--	35.0	--	27.0	--	--

Table 4.--Stomach contents of blue marlin
from Hawaiian International Billfish Tournament 1975.

Food items	Date and number of stomachs containing listed food items					Percent occurrence
	August					
	4	5	6	7	8	
<u>Fish</u>						
Tuna, Scombridae						70
Skipjack tuna, <u>Katsuwonus pelamis</u>	7	8	7	3	8	43
Frigate mackerel, <u>Auxis</u> sp.	2	2	5	-	1	13
Unidentified tuna	6	5	5	1	7	32
Jacks, Carangidae						18
Opelu, <u>Decapterus pinnulatus</u>	4	5	5	1	3	17
Akule, <u>Trachurops crumenophthalmus</u>	-	-	-	1	-	1
Dolphins, Coryphaenidae						9
Mahimahi, <u>Coryphaena hippurus</u>	-	3	1	-	2	8
Pompano dolphin, <u>Coryphaena equiselis</u>	-	-	-	1	-	1
Pelagic spiny puffer, Diodontidae	1	3	1	1	3	12
Surgeonfish, Acanthuridae	-	-	1	-	-	1
Lancetfish, Alepisauridae	2	1	-	-	-	4
Snake mackerel, Gempylidae	1	-	-	-	-	1
Butterflyfish, Chaetodontidae	-	-	-	1	-	1
Goatfish, Mullidae	-	-	1	-	-	1
Needlefish, Belonidae	-	-	-	1	1	3
Halfbeak, Hemiramphidae	-	-	1	-	-	1
Unidentified fish	6	5	5	2	7	33
<u>Invertebrates</u>						
Squid, Decapoda	3	5	4	4	3	25
Empty or everted stomachs	1	1	3	1	4	13
Number of stomachs examined	13	17	19	8	19	
Total:	76					

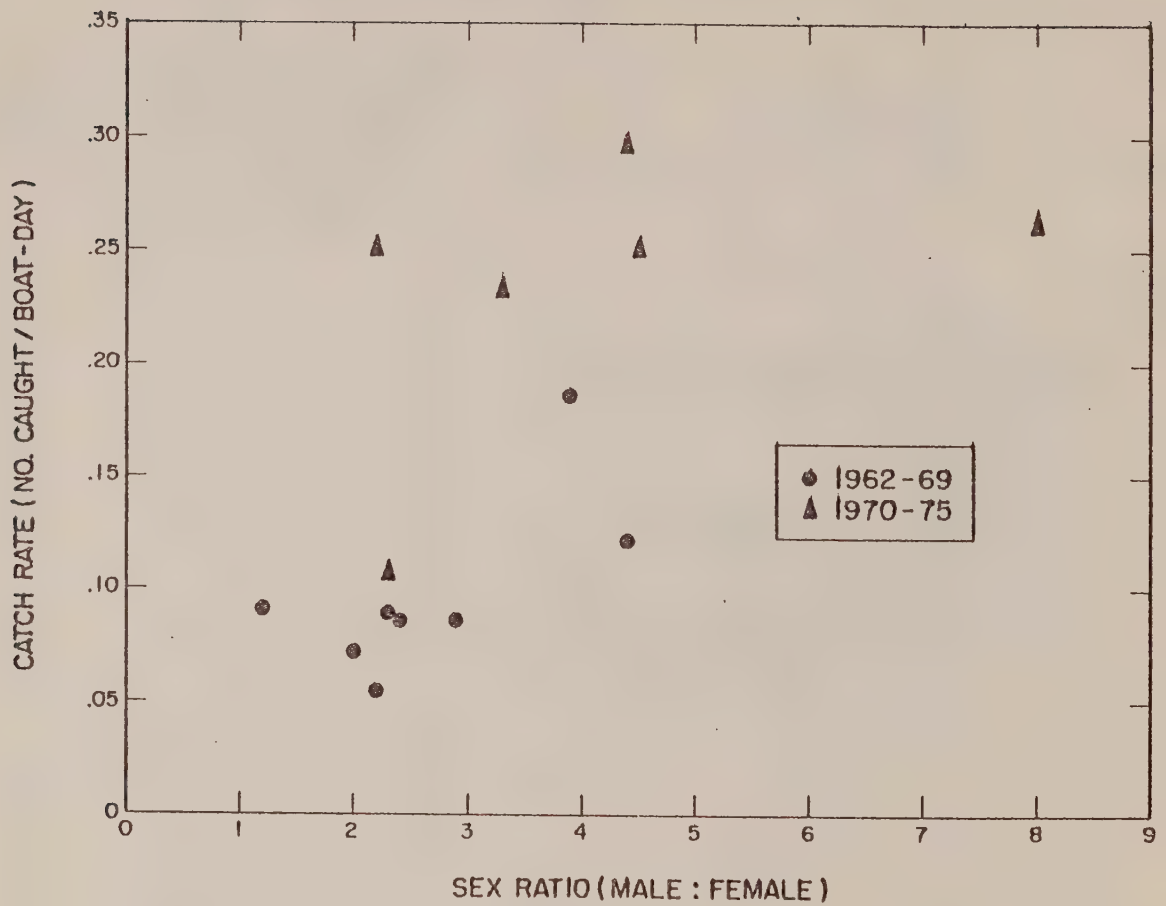


Figure 1.--Plot of blue marlin catch rates on sex ratios.

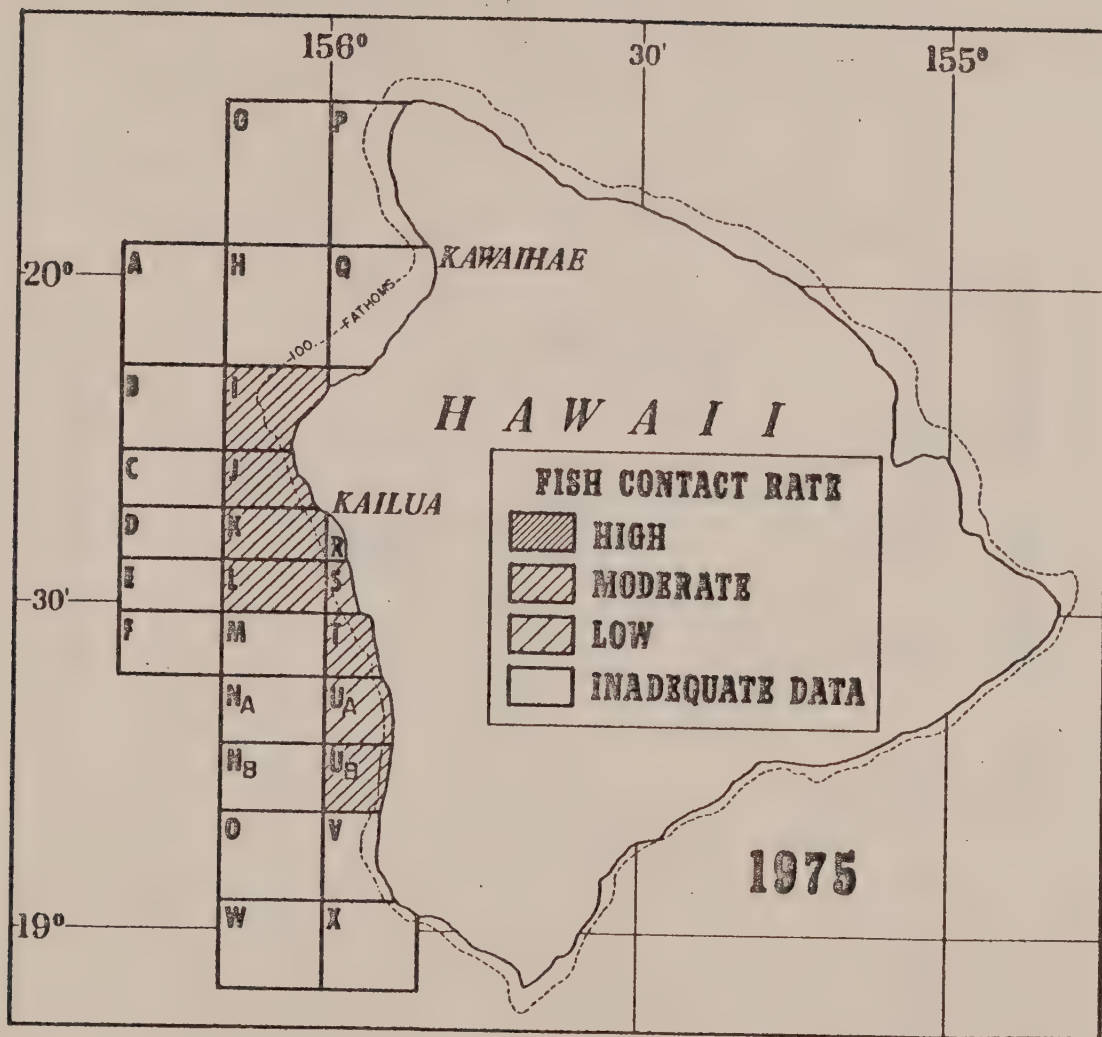


Figure 2.--Strike rates in various fishing areas.

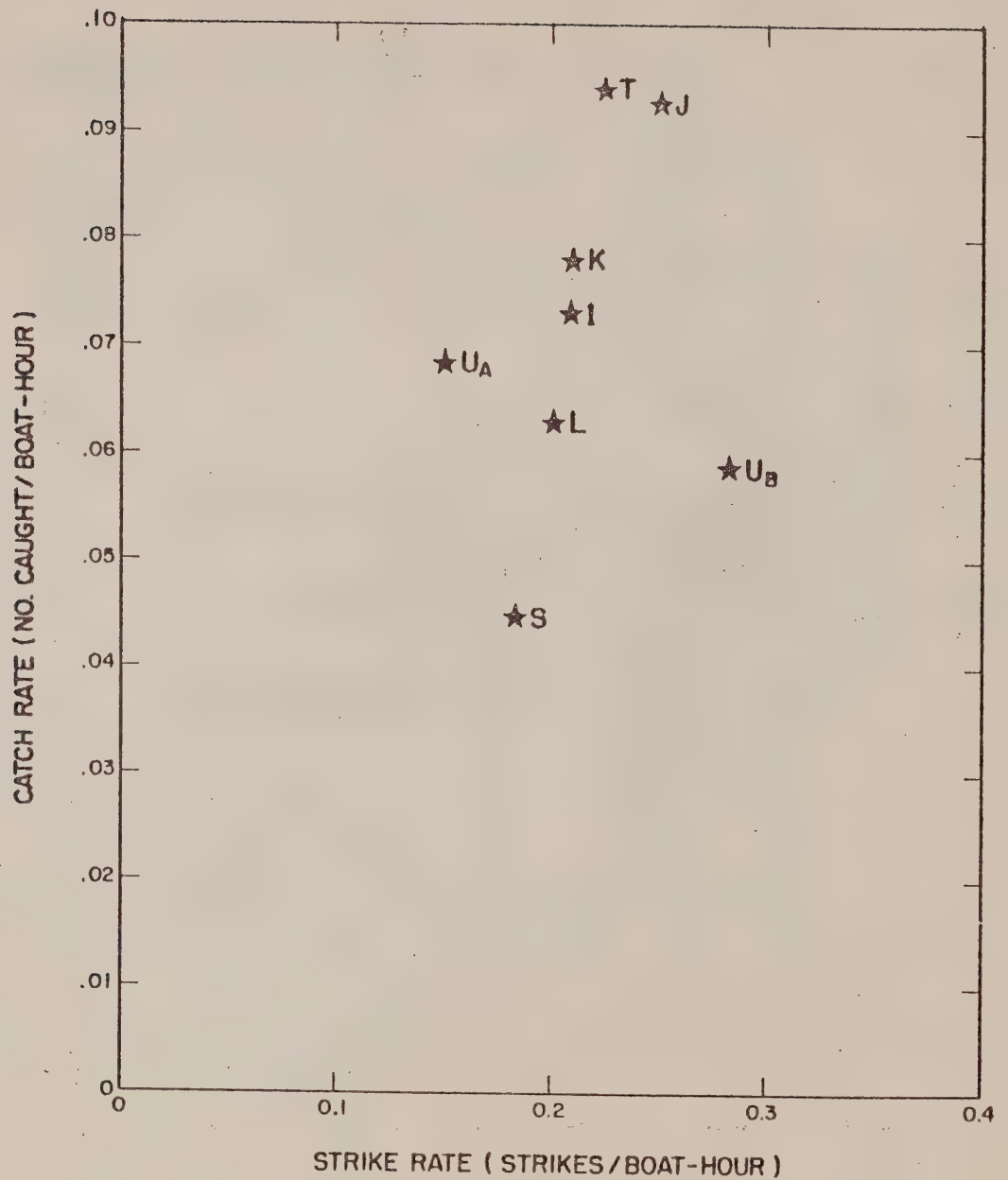


Figure 3.--Strike rates and catch rates of the most fished areas.

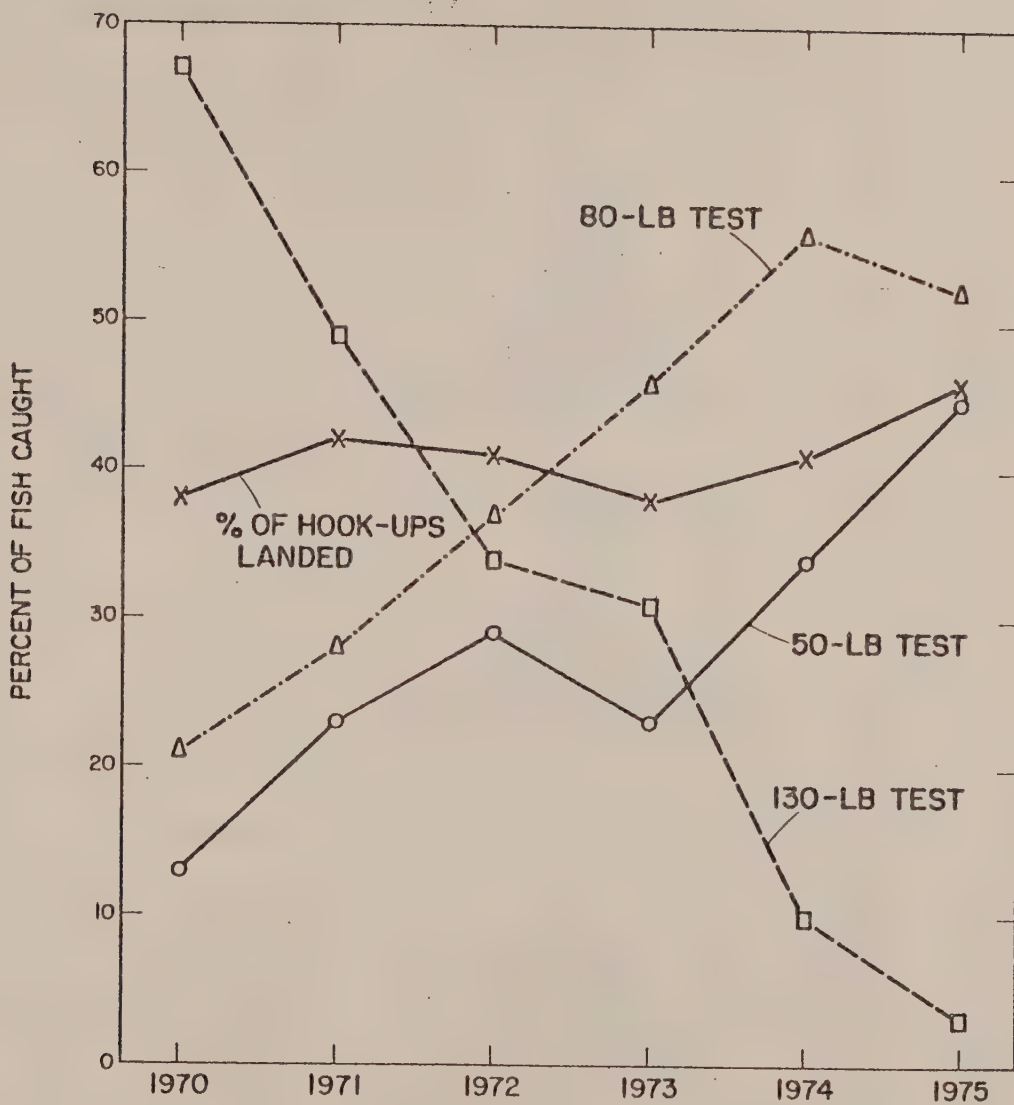


Figure 4.--Proportion of catch landed on lines of various sizes.

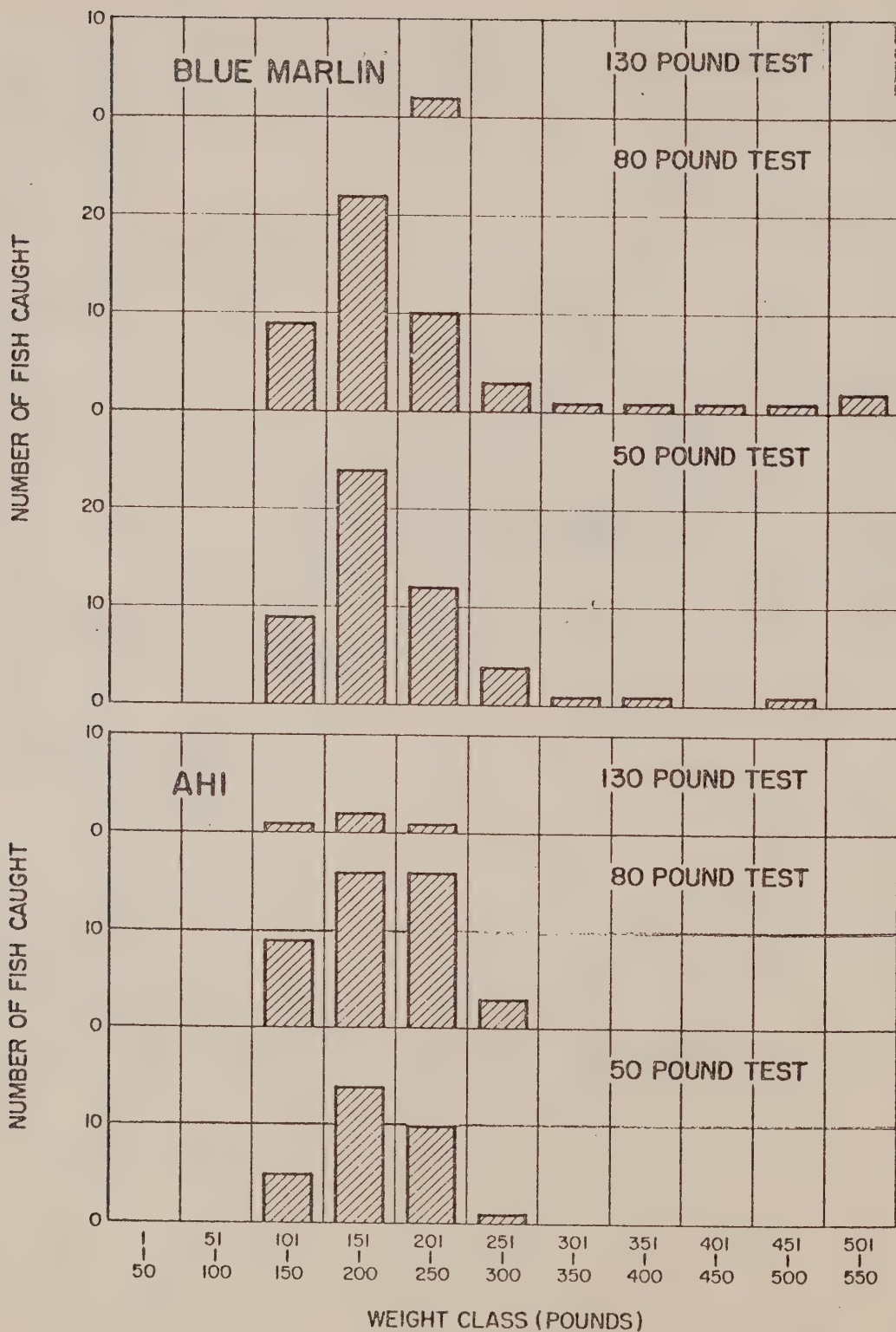


Figure 5.--Frequency distribution of weights of fish caught on various size lines.

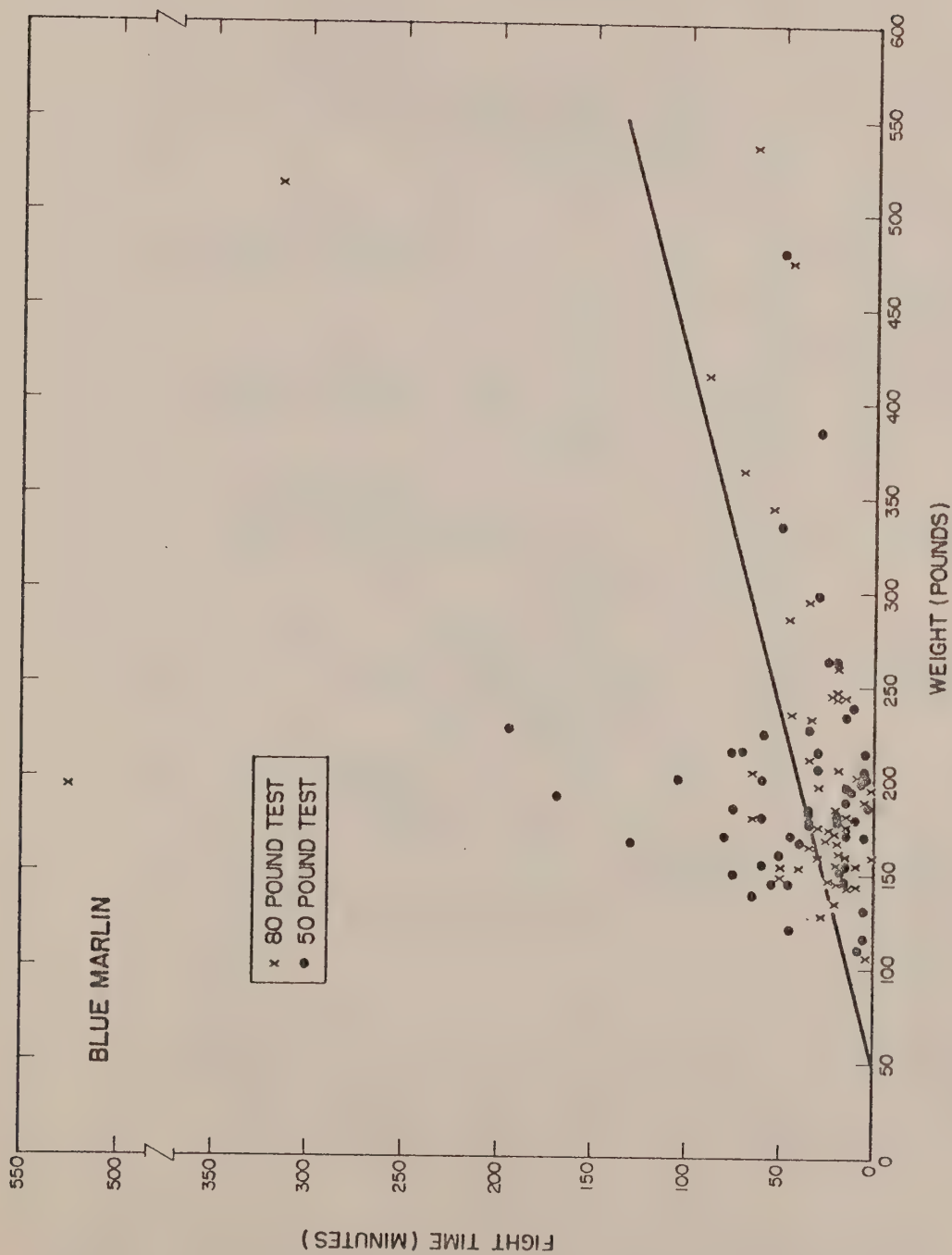


Figure 6.--Relationship of fighting time to weight of blue marlin on 50- and 80-lb test lines.

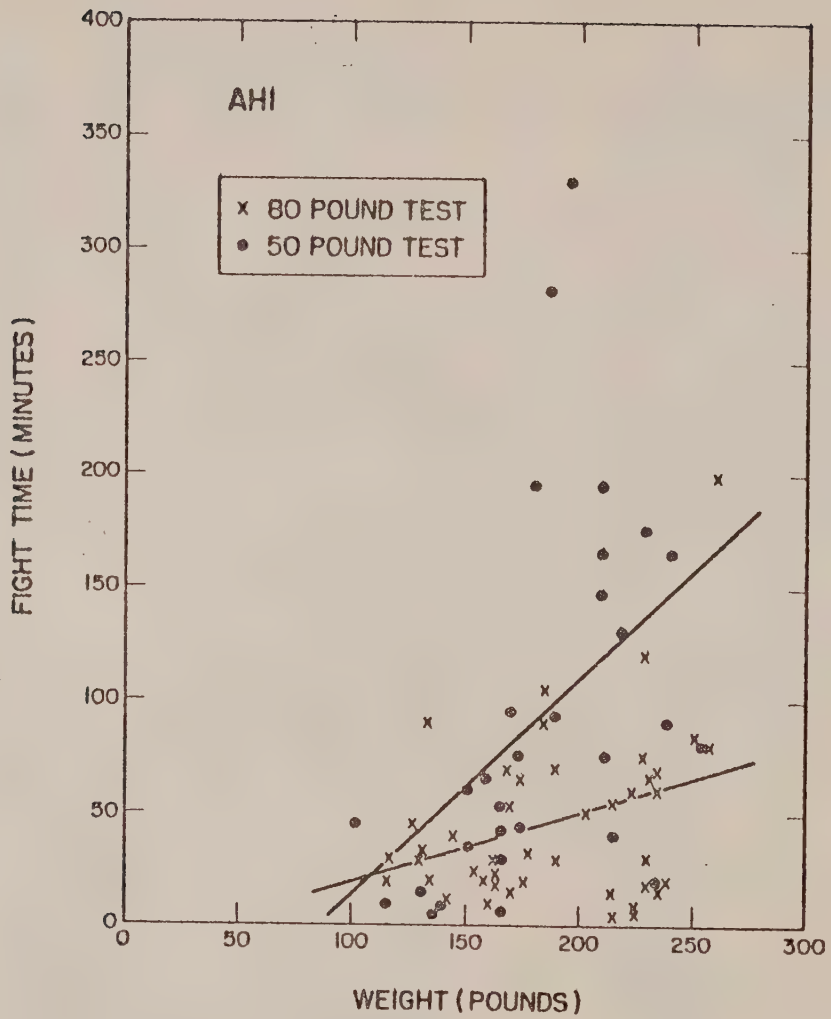


Figure 7.--Relationship of fighting time to weight of ahi on 50- and 80-lb test lines.

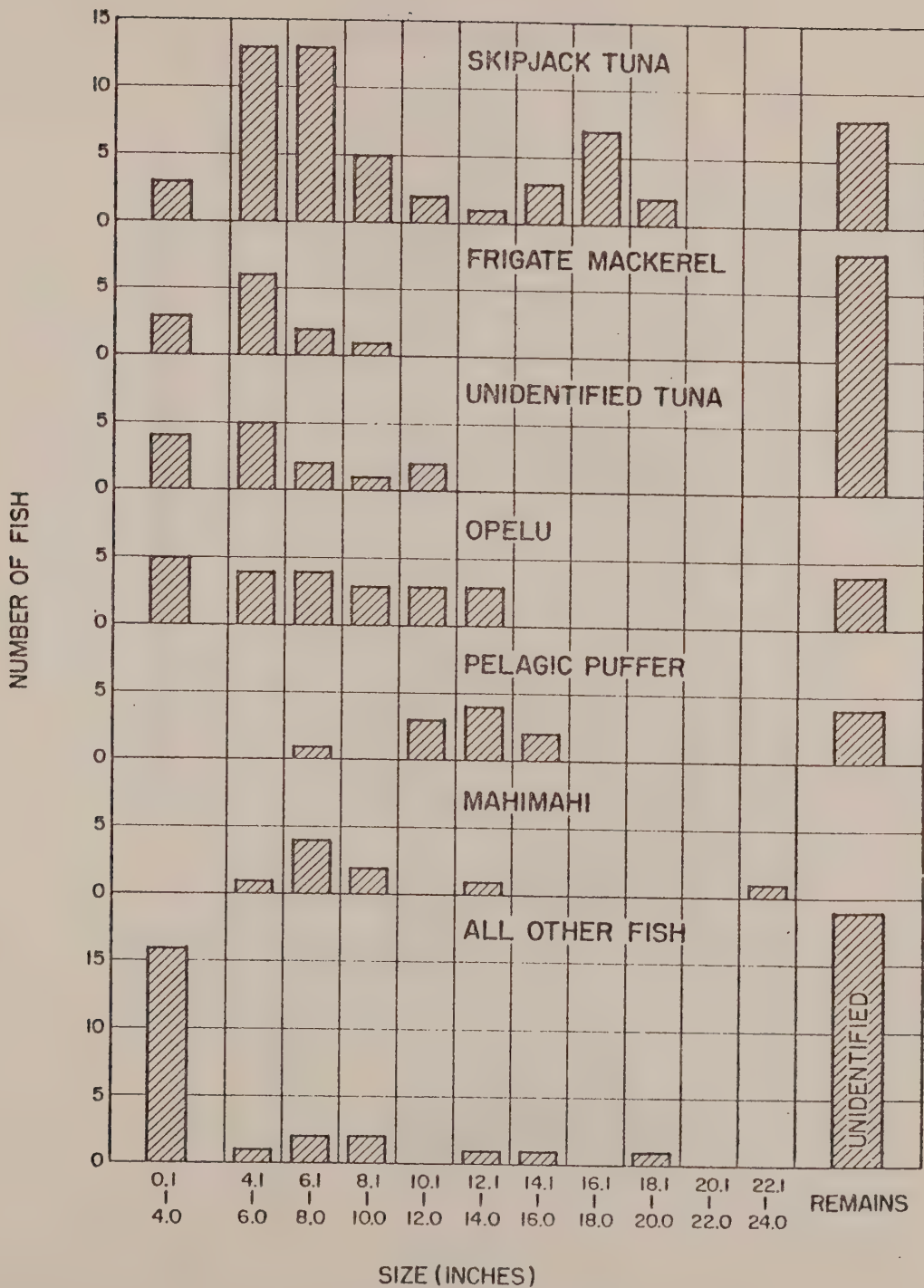


Figure 8.--Numbers and lengths of fish found in blue marlin stomachs.

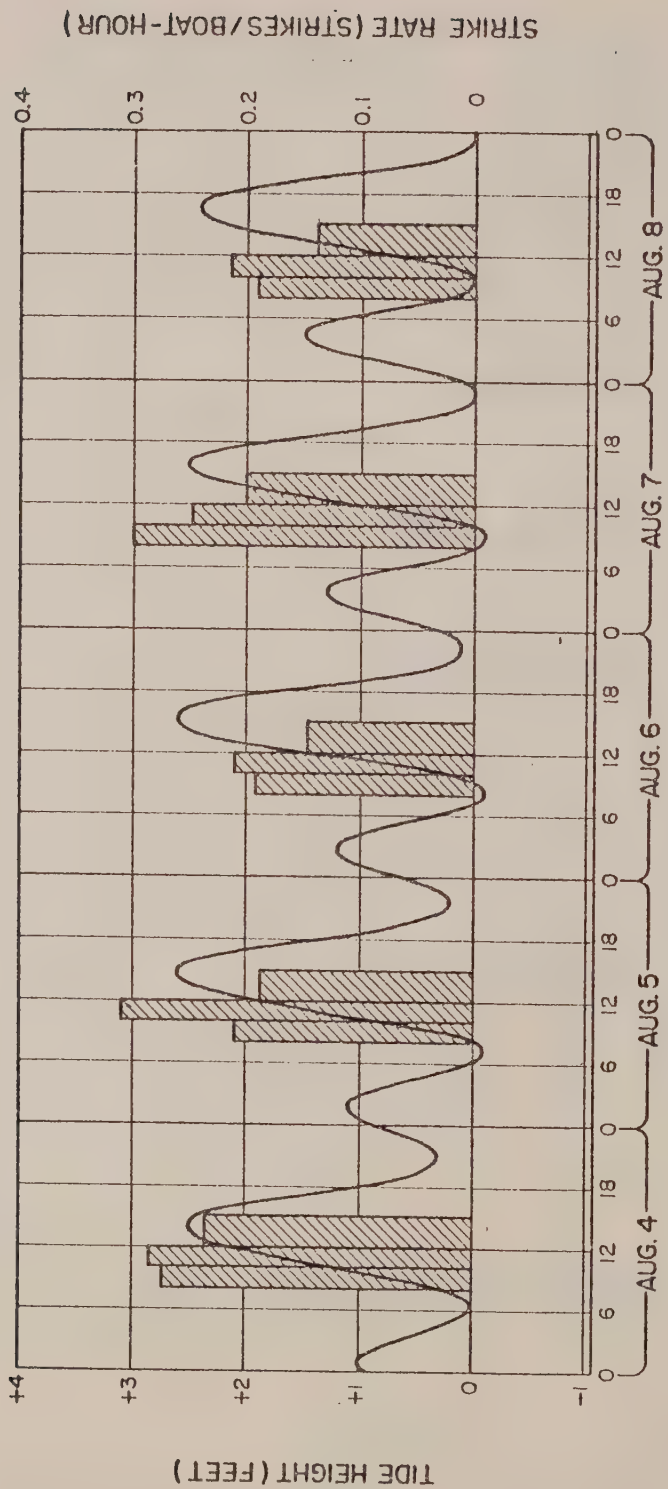


Figure 9.--Strike rates and tide cycle for Hawaiian International Billfish Tournament 1975.

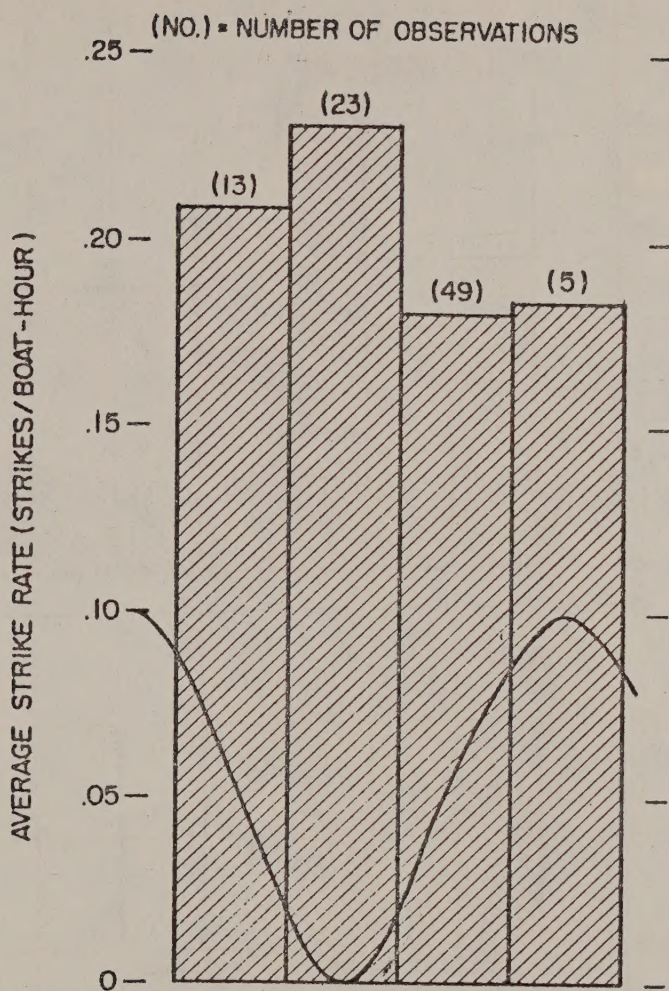


Figure 10.--Average strike rates (HIBT 1970-75)
at various tide phases.

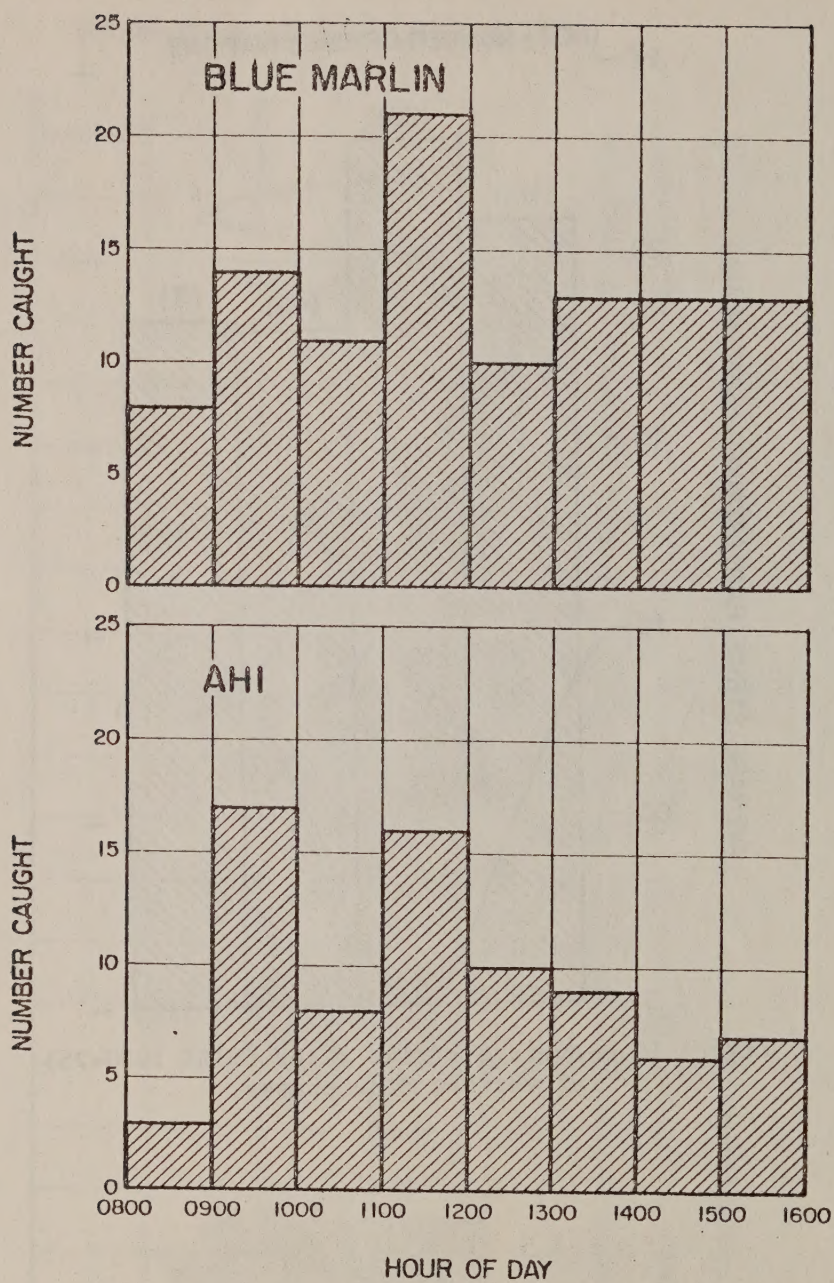


Figure 11.--Fish catch and time of day for blue marlin and ahi.

